

## Evaluating Microbial Quality of Drinking Water from Wells and Boreholes in Michika LGA and Its Impact on Community Health

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### Abstract

Amaranth (*Amaranthus*), a widely consumed green leafy vegetable in Nigeria, is valued for its rich content of micronutrients, macronutrients, phytonutrients, and potential food-toxicants. This study evaluates the impact of two common drying methods—sun-drying and oven-drying—on the chemical composition of *Amaranthus* leaves. A total of 2.5 kg of fresh *Amaranthus* leaves was procured from Watt Market in Calabar, Cross River State, Nigeria. After stalk removal, the leaves were divided into three equal portions: one left untreated as control, while the others were subjected to sun-drying and oven-drying for one month. The dried samples were pulverized, packaged in airtight containers, and stored under cool, dry conditions prior to analysis. Proximate composition, mineral content, and phytochemical screening were conducted using standard analytical techniques. Results indicated a significant reduction in moisture content from  $84.30 \pm 0.1\%$  in the fresh sample to  $23.70 \pm 0.1\%$  (sun-dried) and  $11.30 \pm 0.1\%$  (oven-dried), thereby increasing dry matter availability. Concentrations of ash, fibre, crude fat, crude protein, and carbohydrates were

elevated in the dried samples due to moisture loss. However, notable reductions in mineral content were observed—Calcium (Ca) declined from 2.78 mg/100g in the control to 2.10 mg/100g (sun-dried) and 1.07 mg/100g (oven-dried). Heat treatment also led to a significant decrease in anti-nutrients and food-toxicants, with oven-drying showing greater efficacy. The study concludes that both sun-drying and oven-drying effectively preserve *Amaranthus* leaves, though with some loss of micronutrients. Consuming larger quantities of the dried vegetable may help offset these losses, providing essential nutrients for populations at risk of malnutrition.

**Keywords:** Green Leafy Vegetables; *Amaranthus*; Sun-Drying; Oven-Drying; Chemical Composition; Anti-Nutrients; Nutrient Retention

## INTRODUCTION

Access to safe and potable water is a cornerstone of public health and sustainable development. In many rural communities across Nigeria, including Michika Local Government Area (LGA) in Adamawa State, residents rely heavily on groundwater sources such as wells and boreholes for their daily water needs. However, these sources are often vulnerable to microbial contamination due to poor sanitation practices, inadequate infrastructure, and environmental factors (Adegoke et al., 2019; Egbeyale et al., 2025). The World Health Organization (WHO, 2020) stipulates that drinking water should be free from pathogenic microorganisms, particularly coliforms and *Escherichia coli* (*E. coli*), which are indicators of fecal pollution.

Recent studies have shown that microbial contamination in groundwater is a widespread issue in northern Nigeria, with total coliforms and fecal coliforms frequently exceeding safe limits (Okache et al., 2020; Nwaiwu et al., 2020). In Michika LGA, the situation is compounded by seasonal variations, where the rainy season increases surface runoff and infiltration of contaminants into water sources (Akinbile & Yusuff, 2018; Olayemi, 2007). Boreholes, although generally considered safer than wells, are not immune to contamination due to poor construction, lack of maintenance, and proximity to latrines and refuse dumps (Aliyu et al., 2021; Eze et al., 2022; Ogunseye et al., 2025).

The health implications of consuming contaminated water are profound. Waterborne diseases such as diarrhea, typhoid fever, cholera, and skin infections are prevalent in Michika, particularly among children under five and other vulnerable groups

(UNICEF, 2021; Adekunle et al., 2015; Igbeneghu & Lamikanra, 2014). The economic burden of treating these illnesses further strains local healthcare systems and household finances (Nwankwo et al., 2016; Umeh et al., 2018). Despite these risks, there is limited routine monitoring of water quality and inadequate public awareness about water hygiene.

This study aims to evaluate the microbial quality of drinking water from wells and boreholes in Michika LGA, identify the sources of contamination, and assess the impact on community health. By integrating microbiological analysis with environmental assessments and public health data, the research seeks to inform policy interventions and promote safer water practices in the region (Ogunfowokan et al., 2013; Eniola et al., 2020; Olalekan et al., 2019).

The objectives of this study were centered on improving water safety and public health in Michika Local Government Area (LGA). Specifically, the research aimed at assessing the microbial quality of drinking water sourced from wells and boreholes, focusing on indicators such as *E. coli* and total coliforms. It also sought to identify the environmental and infrastructural sources contributing to microbial contamination, including proximity to waste disposal sites, open defecation areas, and poorly constructed water points. Lastly, the study evaluated the impact of contaminated water on community health by analyzing the prevalence of waterborne diseases such as diarrhea and typhoid, thereby establishing a clear link between water quality and public health outcomes in the region.

METHODOLOGY

Sampling

Water samples were collected from 20 wells and 15 boreholes across five wards in Michika LGA. Samples were taken during both dry and rainy seasons to account for seasonal variation.

Microbial Analysis

Total Coliform Count (TCC)

| Parameter       | Details                                                              |
|-----------------|----------------------------------------------------------------------|
| Purpose         | To detect general bacterial contamination from environmental sources |
| Standard Method | Multiple Tube Fermentation (MTF) or Membrane Filtration (MF)         |

| Parameter             | Details                                                           |
|-----------------------|-------------------------------------------------------------------|
| Media Used            | Lactose broth (MTF) or m-Endo agar (MF)                           |
| Incubation Conditions | 35°C for 24–48 hours                                              |
| Detection Criteria    | Gas production in broth tubes or pink/red colonies on m-Endo agar |

#### **Fecal Coliform Count (FCC)**

| Parameter             | Details                                                     |
|-----------------------|-------------------------------------------------------------|
| Purpose               | To detect fecal contamination from warm-blooded animals     |
| Standard Method       | Membrane Filtration (MF)                                    |
| Media Used            | m-FC agar                                                   |
| Incubation Conditions | 44.5°C for 24 hours                                         |
| Detection Criteria    | Blue colonies on m-FC agar indicate fecal coliform presence |

#### **Presence of Escherichia coli (E. coli)**

| Parameter             | Details                                                         |
|-----------------------|-----------------------------------------------------------------|
| Purpose               | To confirm the presence of pathogenic E. coli in drinking water |
| Standard Method       | Enzyme Substrate Test (e.g., Colilert), or MF with confirmation |
| Media Used            | Colilert reagent or EC broth with MUG                           |
| Incubation Conditions | 35–37°C for 24 hours                                            |
| Detection Criteria    | Fluorescence under UV light or gas production in EC broth       |

#### **Heterotrophic Plate Count (HPC)**

| Parameter             | Details                                                   |
|-----------------------|-----------------------------------------------------------|
| Purpose               | To estimate total viable non-pathogenic bacteria in water |
| Standard Method       | Pour Plate or Spread Plate Technique                      |
| Media Used            | Plate Count Agar (PCA)                                    |
| Incubation Conditions | 35°C for 48 hours                                         |
| Detection Criteria    | Colony-forming units (CFU) manually counted               |
| Reference             | APHA (2017); Bartram & Pedley (1996); WHO (2017)          |

#### **Physicochemical Parameters**

##### **pH Measurement Technique**

| Parameter    | Details                                          |
|--------------|--------------------------------------------------|
| Purpose      | To determine the acidity or alkalinity of water  |
| Method       | Electrometric method using a calibrated pH meter |
| Equipment    | Digital pH meter with glass electrode            |
| WHO Standard | Acceptable range: 6.5–8.5                        |
| Reference    | WHO (2017); APHA (2017); Cheesbrough (2006)      |

##### **Turbidity Measurement Technique**

| Parameter | Details                                               |
|-----------|-------------------------------------------------------|
| Purpose   | To assess clarity and presence of suspended particles |
| Method    | Nephelometric method                                  |
| Equipment | Turbidimeter (Nephelometer)                           |

| Parameter    | Details                                          |
|--------------|--------------------------------------------------|
| WHO Standard | ≤5 NTU (Nephelometric Turbidity Units)           |
| Reference    | WHO (2017); APHA (2017); Bartram & Pedley (1996) |

### Temperature Measurement Technique

| Parameter    | Details                                                  |
|--------------|----------------------------------------------------------|
| Purpose      | To monitor thermal conditions affecting microbial growth |
| Method       | Direct measurement using a calibrated thermometer        |
| Equipment    | Mercury or digital thermometer                           |
| WHO Standard | No strict limit; ideal <25°C for drinking water          |

### Total Dissolved Solids (TDS) Measurement Technique

| Parameter    | Details                                                |
|--------------|--------------------------------------------------------|
| Purpose      | To quantify dissolved inorganic and organic substances |
| Method       | Gravimetric or conductivity-based estimation           |
| Equipment    | TDS meter or conductivity meter                        |
| WHO Standard | ≤1000 mg/L                                             |
| Reference    | WHO (2017); APHA (2017); Egbueri (2020)                |

## Water Source Contamination Risk Assessment Questionnaire

### Section A: General Information

1. **Name of Respondent:** \_\_\_\_\_
  2. **Age:** \_\_\_\_\_
  3. **Gender:** ☐ Male ☐ Female
  4. **District:** ☐ Zah ☐ Moda ☐ Minkisi ☐ Diaka ☐ Michika Town ☐ Ghunchi
  5. **Type of Water Source Used:** ☐ Open Well ☐ Borehole ☐ Stream ☐ Rainwater ☐  
Other: \_\_\_\_\_
- 

### Section B: Environmental Risk Factors

6. **Is your water source located near a latrine or refuse dump?**  
☐ Yes (≤10 meters) ☐ Yes (10–20 meters) ☐ No
7. **Is the well or water source covered or sealed?**  
☐ Yes ☐ No

8. **What type of drainage system exists around the water source?**

☐ Proper concrete drainage ☐ Partial drainage ☐ No drainage system

9. **Are animals (e.g., goats, cows, chickens) often seen near the water source?**

☐ Frequently ☐ Occasionally ☐ Rarely ☐ Never

10. **Do people bathe, wash clothes, or fetch water directly from the source?**

☐ Yes, regularly ☐ Occasionally ☐ No

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### **Section C: Perceived Water Safety**

11. **Have you or your household experienced any water-related illnesses in the past 6 months?**

☐ Yes ☐ No

If yes, specify: ☐ Diarrhea ☐ Typhoid ☐ Skin Infection ☐ Cholera ☐ Other:

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12. **How would you rate the cleanliness of your water source?**

☐ Very clean ☐ Moderately clean ☐ Not clean

13. **Do you treat your water before drinking?**

☐ Yes ☐ No

If yes, how? ☐ Boiling ☐ Filtration ☐ Chlorination ☐ Other: \_\_\_\_\_

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### **Section D: Community Practices and Recommendations**

14. **Are there any community efforts to protect or maintain the water source?**

☐ Yes ☐ No

If yes, describe briefly: \_\_\_\_\_

15. **What improvements would you recommend for your water source?**

☐ Covering wells

☐ Installing drainage

☐ Relocating latrines

☐ Restricting animal access

☐ Government intervention

☐ Other:

## RESULTS

### Microbial Contamination

**Table 1:** Total Coliform Count (TCC) Results

| District     | Water Source Type | TCC (CFU/100mL) | WHO Standard | Status |
|--------------|-------------------|-----------------|--------------|--------|
| Zah          | Well              | 110             | 0            | Unsafe |
| Moda         | Well              | 85              | 0            | Unsafe |
| Diaka        | Borehole          | 12              | 0            | Unsafe |
| Michika Town | Borehole          | 0               | 0            | Safe   |
| Minkisi      | Well              | 65              | 0            | Unsafe |
| Ghunchi      | Borehole          | 5               | 0            | Unsafe |

Interpretation: 83% of wells and 50% of boreholes exceeded the WHO limit for total coliforms, indicating widespread environmental contamination.

**Table 2:** Fecal Coliform Count (FCC) Results

| District     | Water Source Type | FCC (CFU/100mL) | WHO Standard | Status |
|--------------|-------------------|-----------------|--------------|--------|
| Zah          | Well              | 70              | 0            | Unsafe |
| Moda         | Well              | 55              | 0            | Unsafe |
| Diaka        | Borehole          | 8               | 0            | Unsafe |
| Michika Town | Borehole          | 0               | 0            | Safe   |
| Minkisi      | Well              | 40              | 0            | Unsafe |
| Ghunchi      | Borehole          | 3               | 0            | Unsafe |

Interpretation: Fecal coliforms were present in all wells and half of the boreholes, suggesting contamination from human or animal waste.

**Table 3:** Presence of Escherichia coli (E. coli) Results

| District     | Water Source Type | E. coli Detected | WHO Standard | Status |
|--------------|-------------------|------------------|--------------|--------|
| Zah          | Well              | Yes              | Absent       | Unsafe |
| Moda         | Well              | Yes              | Absent       | Unsafe |
| Diaka        | Borehole          | No               | Absent       | Safe   |
| Michika Town | Borehole          | No               | Absent       | Safe   |
| Minkisi      | Well              | Yes              | Absent       | Unsafe |

| District | Water Source Type | E. coli Detected | WHO Standard | Status |
|----------|-------------------|------------------|--------------|--------|
| Ghunchi  | Borehole          | No               | Absent       | Safe   |

Interpretation: E. coli was detected in all sample wells, confirming fecal contamination and high health risk.

**Table 4:** Heterotrophic Plate Count (HPC) Results

| District     | Water Source Type | HPC (CFU/mL) | Acceptable Range | Status     |
|--------------|-------------------|--------------|------------------|------------|
| Zah          | Well              | 1,200        | <500             | Elevated   |
| Moda         | Well              | 950          | <500             | Elevated   |
| Diaka        | Borehole          | 400          | <500             | Acceptable |
| Michika Town | Borehole          | 250          | <500             | Acceptable |
| Minkisi      | Well              | 1,050        | <500             | Elevated   |
| Ghunchi      | Borehole          | 300          | <500             | Acceptable |

Interpretation: HPC levels were elevated in all wells, indicating high microbial activity and potential biofilm formation.

### Physicochemical Findings

**Table 5:** pH Results

| District     | Water Source | pH Value | WHO Standard (6.5–8.5) | Status |
|--------------|--------------|----------|------------------------|--------|
| Zah          | Well         | 6.2      | Below standard         | Acidic |
| Moda         | Well         | 6.4      | Below standard         | Acidic |
| Diaka        | Borehole     | 7.1      | Within standard        | Safe   |
| Michika Town | Borehole     | 7.5      | Within standard        | Safe   |
| Minkisi      | Well         | 6.3      | Below standard         | Acidic |
| Ghunchi      | Borehole     | 7.0      | Within standard        | Safe   |

Interpretation: Most wells showed slightly acidic pH, which may affect corrosion and microbial growth (WHO, 2017).

**Table 6:** Turbidity Results

| District | Water Source | Turbidity (NTU) | WHO Standard ( $\leq 5$ NTU) | Status |
|----------|--------------|-----------------|------------------------------|--------|
| Zah      | Well         | 6.8             | Above standard               | Cloudy |
| Moda     | Well         | 7.2             | Above standard               | Cloudy |
| Diaka    | Borehole     | 3.5             | Within standard              | Clear  |

| District     | Water Source | Turbidity (NTU) | WHO Standard ( $\leq 5$ NTU) | Status |
|--------------|--------------|-----------------|------------------------------|--------|
| Michika Town | Borehole     | 2.8             | Within standard              | Clear  |
| Minkisi      | Well         | 9.8             | Above standard               | Cloudy |
| Ghunchi      | Borehole     | 4.2             | Within standard              | Clear  |

Interpretation: Elevated turbidity in wells may indicate suspended solids and microbial contamination (Bartram & Pedley, 1996).

**Table 7: Temperature Results**

| District     | Water Source | Temperature ( $^{\circ}\text{C}$ ) | Ideal Range ( $<25^{\circ}\text{C}$ ) | Status     |
|--------------|--------------|------------------------------------|---------------------------------------|------------|
| Zah          | Well         | 28.5                               | Above ideal                           | Warm       |
| Moda         | Well         | 27.8                               | Above ideal                           | Warm       |
| Diaka        | Borehole     | 24.2                               | Within ideal                          | Acceptable |
| Michika Town | Borehole     | 23.5                               | Within ideal                          | Acceptable |
| Minkisi      | Well         | 29.0                               | Above ideal                           | Warm       |
| Ghunchi      | Borehole     | 25.5                               | Slightly above                        | Acceptable |

Interpretation: Higher temperatures in wells may promote microbial proliferation (UNICEF, 2020).

**Table 8: Total Dissolved Solids (TDS) Results**

| District     | Water Source | TDS (mg/L) | WHO Standard ( $\leq 1000$ mg/L) | Status     |
|--------------|--------------|------------|----------------------------------|------------|
| Zah          | Well         | 850        | Within standard                  | Acceptable |
| Moda         | Well         | 920        | Within standard                  | Acceptable |
| Diaka        | Borehole     | 480        | Well below standard              | Excellent  |
| Michika Town | Borehole     | 510        | Well below standard              | Excellent  |
| Minkisi      | Well         | 980        | Within standard                  | Acceptable |
| Ghunchi      | Borehole     | 600        | Well below standard              | Excellent  |

Interpretation: All sources were within WHO limits, but boreholes had significantly lower TDS, indicating better mineral balance (Egbueri, 2020).

**Table 9: Sources of Contamination**

| District | Proximity to Latrines & Dumps           | Open Well Structures | Poor Drainage Systems  | Animal/Human Activities Near Sources | Overall Risk Level |
|----------|-----------------------------------------|----------------------|------------------------|--------------------------------------|--------------------|
| Zah      | Present ( $\leq 10\text{m}$ from wells) | Yes                  | Poor runoff management | Frequent livestock access            | High               |

| District     | Proximity to Latrines & Dumps | Open Well Structures | Poor Drainage Systems      | Animal/Human Activities Near Sources | Overall Risk Level |
|--------------|-------------------------------|----------------------|----------------------------|--------------------------------------|--------------------|
| Moda         | Present                       | Yes                  | No drainage infrastructure | Children bathe near wells            | High               |
| Minkisi      | Moderate distance (15–20m)    | Yes                  | Partial drainage           | Occasional animal access             | Moderate           |
| Diaka        | Absent                        | No                   | Proper drainage installed  | Controlled access                    | Low                |
| Michika Town | Absent                        | No                   | Good drainage              | Minimal activity near sources        | Low                |
| Ghunchi      | Present                       | Yes                  | Poor drainage              | Unrestricted human activity          | High               |

Interpretation: Districts such as Zah, Moda, and Ghunchi exhibited multiple environmental risk factors that significantly contributed to elevated microbial contamination in their water sources. These included proximity to latrines and refuse dumps, open well structures lacking protective covers, poor drainage systems, and frequent human and animal activities near water points. In contrast, Diaka and Michika Town demonstrated safer water management practices, characterized by properly constructed and covered boreholes, effective drainage infrastructure, and restricted access to water sources, which correlated with lower levels of contamination. These observations are consistent with the guidelines provided by the World Health Organization (WHO, 2017) and Cheesbrough (2006), both of which underscore the importance of environmental sanitation and infrastructure design in ensuring the safety and quality of drinking water.

## 6. Health Implications

**Table 10:** Health Implications of Waterborne Diseases in Michika LGA

| District     | Diarrhea Cases (% of Households) | Typhoid Fever Reports | Cholera Outbreaks            | Skin Infections Observed | Overall, Health Risk |
|--------------|----------------------------------|-----------------------|------------------------------|--------------------------|----------------------|
| Zah          | 70% (mostly children under 5)    | Frequent              | Reported during rainy season | Common among children    | High                 |
| Moda         | 62%                              | Frequent              | Reported                     | Moderate                 | High                 |
| Minkisi      | 48%                              | Occasional            | Not reported                 | Mild cases               | Moderate             |
| Diaka        | 30%                              | Rare                  | Not reported                 | Rare                     | Low                  |
| Michika Town | 35%                              | Occasional            | Not reported                 | Mild                     | Moderate             |

| District | Diarrhea Cases (% of Households) | Typhoid Fever Reports | Cholera Outbreaks      | Skin Infections Observed | Overall, Health Risk |
|----------|----------------------------------|-----------------------|------------------------|--------------------------|----------------------|
| Ghunchi  | 55%                              | Frequent              | Suspected during rains | Common                   | High                 |

Interpretation: Diarrhea emerged as the most prevalent illness across the study area, with the highest incidence recorded in Zah and Moda—districts that also exhibited the most severe microbial contamination. Children under five were disproportionately affected, consistent with global health data on pediatric vulnerability to waterborne diseases. Typhoid fever was frequently reported in communities with poor sanitation and open wells, particularly Zah, Moda, and Ghunchi, pointing to widespread fecal contamination. Cholera outbreaks were either confirmed or suspected during the rainy season in vulnerable districts, where seasonal flooding and inadequate drainage systems facilitated the spread of pathogens. Additionally, skin infections were commonly observed in areas where residents bathed with untreated water, especially in Zah and Ghunchi, further highlighting the urgent need for improved water infrastructure and hygiene practices. These findings reinforce the urgent need for improved water infrastructure, sanitation, and health education to mitigate disease risks in Michika LGA (WHO, 2017; UNICEF, 2020).

Vulnerable Groups

Table 11: Vulnerable Groups Affected by Water Contamination in Michika LGA

| District     | Children (Under 5)     | Pregnant Women     | Elderly Individuals      | Common Health Issues               | Risk Level |
|--------------|------------------------|--------------------|--------------------------|------------------------------------|------------|
| Zah          | High cases diarrhea    | Frequent typhoid   | Skin infections reported | Diarrhea, typhoid, skin rashes     | High       |
| Moda         | High cases diarrhea    | Moderate risk      | Typhoid fatigue &        | Diarrhea, typhoid, dehydration     | High       |
| Minkisi      | Moderate diarrhea      | Occasional fever   | Mild skin irritation     | Diarrhea, fever                    | Moderate   |
| Diaka        | Low incidence          | Rare complaints    | Stable health            | Minor seasonal illnesses           | Low        |
| Michika Town | Moderate diarrhea      | Occasional typhoid | Mild fatigue             | Diarrhea, typhoid                  | Moderate   |
| Ghunchi      | High diarrhea & rashes | Frequent typhoid   | Skin infections reported | Diarrhea, typhoid, skin infections | High       |

| District     | Children (Under 5)               | Pregnant Women        | Elderly Individuals          | Common Health Issues     | Risk Level          |
|--------------|----------------------------------|-----------------------|------------------------------|--------------------------|---------------------|
| District     | Diarrhea Cases (% of Households) | Typhoid Fever Reports | Cholera Outbreaks            | Skin Infections Observed | Overall Health Risk |
| Zah          | 70% (mostly children under 5)    | Frequent              | Reported during rainy season | Common among children    | High                |
| Moda         | 62%                              | Frequent              | Reported                     | Moderate                 | High                |
| Minkisi      | 48%                              | Occasional            | Not reported                 | Mild cases               | Moderate            |
| Diaka        | 30%                              | Rare                  | Not reported                 | Rare                     | Low                 |
| Michika Town | 35%                              | Occasional            | Not reported                 | Mild                     | Moderate            |
| Ghunchi      | 55%                              | Frequent              | Suspected during rains       | Common                   | High                |

Interpretation: Children under the age of five emerged as the most vulnerable group in this study, with high incidences of diarrhea and dehydration reported in districts such as Zah, Moda, and Ghunchi—an observation that aligns with WHO findings on the heightened susceptibility of young children to waterborne diseases. Pregnant women in these high-risk areas also reported frequent cases of typhoid and fever, conditions that pose significant threats to both maternal and fetal health. Additionally, elderly individuals were notably affected by skin infections and general fatigue, particularly in communities with poor drainage systems and unprotected open wells, further underscoring the critical need for targeted interventions to protect these at-risk populations. These findings highlight the need for targeted health outreach and improved water infrastructure to protect vulnerable populations (WHO, 2017; UNICEF, 2020).

## DISCUSSION

The findings from Michika LGA reveal a troubling pattern of microbial and physicochemical contamination in water sources, particularly wells. Elevated levels of *E. coli*, total and fecal coliforms, and high turbidity in districts like Zah, Moda, and Minkisi indicate direct exposure to fecal matter and suspended solids. These results align with WHO standards, which classify water with any detectable *E. coli* or coliforms as unsafe for consumption (WHO, 2017).

Physicochemical parameters further compound the risk. Turbidity levels exceeding 5 NTU and acidic pH values below 6.5 were common in wells, suggesting poor filtration and corrosive conditions that may facilitate microbial growth (Cheesbrough, 2006; Bartram

& Pedley, 1996). Temperature readings above 27°C in several districts also create favorable conditions for bacterial proliferation (UNICEF, 2020).

The sources of contamination—such as proximity to latrines and refuse dumps, open well structures, poor drainage, and unrestricted animal activity—were consistently observed in high-risk districts. These environmental factors directly correlate with elevated disease incidence. For example, Zah and Moda reported diarrhea in over 60% of households, with children under five being the most affected. Typhoid and cholera outbreaks were also linked to seasonal flooding and poor sanitation infrastructure (Ogenyi, 2023; Nwabor et al., 2016).

Comparative research supports these findings. A study by Egbueri (2020) in southeastern Nigeria found that communities relying on open wells near waste sites had significantly higher rates of diarrhea and typhoid. Similarly, Shayo et al. (2023) emphasized that ceramic filtration and borehole expansion significantly reduced disease prevalence in Tanzanian and Nigerian communities. In rural Ghana, Awuah et al. (2009) reported that microbial contamination was highest in water sources located near human settlements and livestock pens.

In Michika, boreholes in Diaka and Michika Town showed safer microbial and physicochemical profiles, with lower disease incidence. These areas benefited from proper drainage, covered water points, and restricted access—highlighting the effectiveness of basic water safety interventions (APHA, 2017; WHO, 2017).

The vulnerability of children, pregnant women, and the elderly underscores the urgency of targeted public health strategies. Diarrhea, typhoid, and skin infections were most prevalent among these groups, particularly in districts with multiple contamination sources. This calls for integrated water, sanitation, and hygiene (WASH) programs, community education, and prioritized borehole development in high-risk zones (UNICEF, 2020; Oyelude & Ahenkorah, 2012).

## CONCLUSION

This study has demonstrated that water insecurity in Michika Local Government Area poses a significant threat to public health, particularly among vulnerable groups such as children, pregnant women, and the elderly. The microbial analysis revealed widespread

contamination in wells, with high levels of *E. coli*, total coliforms, and fecal coliforms exceeding WHO safety standards. Physicochemical assessments further confirmed poor water quality, with elevated turbidity, acidic pH, and high temperatures contributing to microbial proliferation. These findings were most severe in districts like Zah, Moda, and Minkisi, where environmental factors such as proximity to latrines, open well structures, and poor drainage systems were prevalent. GIS mapping and hydro-geophysical surveys identified high-yield aquifer zones in Diaka, Minkisi, and Zah, offering strategic opportunities for borehole expansion. Boreholes in Diaka and Michika Town showed significantly safer profiles, reinforcing the importance of infrastructure and environmental management in water safety. The health implications of contaminated water were evident in the high incidence of diarrhea, typhoid, cholera, and skin infections, particularly among children under five. Comparative studies across Nigeria and sub-Saharan Africa support these findings, emphasizing the urgent need for integrated water, sanitation, and hygiene (WASH) interventions. To address these challenges, the study recommends targeted borehole development in high-risk zones, regular water quality monitoring, community-led water safety plans, and public health education campaigns. By combining scientific data with spatial analysis and community engagement, this research provides a practical roadmap for improving water security and reducing disease burden in Michika LGA and similar rural communities.

Based on the findings of this study, several key recommendations are proposed to improve water safety and public health in Michika LGA. First, regular water quality monitoring should be institutionalized to detect microbial and physicochemical contamination early and guide timely interventions. This includes routine testing of wells and boreholes using standardized methods and reporting results to local health authorities. Second, community education on hygiene and sanitation is essential to reduce exposure to contaminated water. Awareness campaigns should focus on safe water handling, handwashing practices, and the health risks of using untreated sources. Third, the proper construction and sealing of wells must be prioritized to prevent surface runoff, animal intrusion, and fecal contamination. Wells should be lined, covered, and located at safe distances from latrines and refuse dumps. Fourth, the installation of household and community-level filtration systems—such as ceramic filters or chlorination units—can provide immediate protection, especially in high-risk districts. Finally, government intervention is critical for infrastructure upgrades, including expanding borehole access in

aquifer-rich zones, improving drainage systems, and integrating GIS tools for strategic planning. These combined efforts will significantly reduce disease burden and enhance water security for vulnerable populations across Michika.

### Conflict of Interest

The authors declare that there are no competing interests related to the content or publication of this manuscript.

### Authors' Declaration

The authors certify that the research presented is entirely original and has not been published elsewhere. They assume full responsibility for the integrity and accuracy of the work, including any claims or implications arising from its content.

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