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Dependence of Rural Communities on Unsafe Water Sources - Case study of Tinda Village, Northeastern Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. Author OZW designed the study, performed the statistical analysis, and wrote the first draft of the manuscript. Authors DBO and TDA wrote the protocol and managed the analyses of the study. Author CJM and ASO managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Accessibility of rural dwellers, particularly in Northern Nigeria, to basic water services has been a significant challenge over the years, thereby contributing significantly to the high mortality rates associated with waterborne disease recorded in the region. Recent information is required about the state of water facilities in some of these marginalized communities to proffer sustainable solutions. This community-based survey explored the water services available to rural dwellers in Tinda village, Gombe State. Data was collected via participant and community observation. Grab water samples were also obtained and analyzed for physicochemical and bacteriological parameters using standard methods. The village lacked an improved drinking water source. The major source present was a dam, while other sources available were a river and an unsanitary well. The surface water samples were turbid and coloured, while the well water was slightly turbid and coloured. The lead, iron, and manganese levels of the surface water samples were above

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WHO permissible limits. *E.coli* was detected in both the river and well water samples, while *salmonella sp.* was detected in all the water sources. Disinfection of the water samples with a water guard (local chlorine disinfectant) significantly reduced the microbial load. However, the water was still unsafe for drinking. The current state of water facilities in Tinda village is deplorable. With the primary water sources polluted with both heavy metals and microbes, the health of rural dwellers remains at stake.

Keywords: Rural dwellers; unimproved water; unsafe water; Northern Nigeria; water quality; Salmonella sp.

1. INTRODUCTION

A report revealed that 144 million people still depended on surface water for drinking and domestic purposes [1]. The pollution of a significant portion of surface waters with faecal matter puts such individuals at risk of contracting waterborne diseases like viral hepatitis, typhoid, cholera, dysentery, polio, and diarrhea. This is one reason why achieving Target 6.1 of the Sustainable Development Goal 6 (achieving universal and equitable access to safe and affordable drinking water for all) is of utmost importance [2]. Even though the SDGs are global targets, the progress made so far seems to be one-sided. Surveys that have been carried out revealed that the developed countries and the developing countries were miles apart in their respective access to basic WASH facilities [1]. A report by WASH Watch [3] revealed that around 94% of the population in Northern America and Europe had safely managed drinking water. In comparison, only approximately 24% of the people in sub-Saharan Africa (SSA) had such. SSA has also been classified as the region with the highest population without access to safe water [4].

There are also extreme spatial inequalities within countries; examples of these are the cases experienced by marginalized communities in remote rural areas, discriminated groups, minority tribes, dwellings, and slum-dwellers in urban areas. For such people, access to water and sanitation is often a significant problem that becomes part of daily life [1,4]. Poor and marginalized members of a society usually have the least say in the distribution of water resources. This is why such people are at the bottom of the ladder or the least priority when water-related projects arise, even though the benefit derived from improved access is most significant for the poorest people and those in the most vulnerable situations [4,5]. Rural dwellers are particularly affected as it has been estimated that 80% of the global population without access to safely managed drinking water services reside in rural communities [1]. A study that monitored the progress made in WASH in SSA revealed that poor rural households were 29 times less likely to access improved water and contributed significantly to under-5 mortality in the region [6,7].

It was estimated that around 90% of rural Nigerians defecated in the open, while 51% of the rural areas did not have access to improved water [8]. In south-western Nigeria, most rural communities lacked access to improved water sources due to the absence of adequate water infrastructure and sustainable maintenance schemes, thereby leading to the continuous dependence of rural dwellers on surface water sources [9]. Another survey in Akwa Ibom, South-southern Nigeria, revealed that most water projects in the state were focused on urban areas, while the rural water projects were mostly sidelined. This situation was also reported to leave the rural dwellers with no choice but to depend on polluted surface water sources [10]. Furthermore, surveys from Northern Nigeria have also revealed that most of the population in the region depended on unimproved sources, particularly surface water [11,12]. The region is regarded as the part of the country most affected by the impacts of inaccessibility to clean and drinking water due to the high rate of poverty, relatively dense population, and reduced political will [13]. The peculiarities of this region reveal why urgent attention is required.

Hence, this study assessed the water facilities available to remote rural dwellers in Tinda village, Gombe State, Northeastern Nigeria, to determine how much effort is required to achieve SDG 6.

2. METHODS

2.1 Sampling Sites

The study was conducted in Tinda village, Gombe State, in the Northeastern region of

Nigeria. The rural village located in Dukku Local Government Area has a Latitude of $10^{o}47'14.23"$ and a longitude of $10^{0}53'26.58"$. The village was relatively homogenous, as the significant occupation practiced was farming, and the common ethnic group was Fulani. The low-income community lacked basic social infrastructure, and the majority of the dwellers were uneducated.

2.2 Data Collection Procedure

2.2.1 Community observation

Qualitative data was obtained via general observation. The research group dwelled with the villagers for a couple of days, monitoring how they went about their day-to-day activities. The villagers' primary water sources for drinking and household purposes were identified and appropriately noted by the research team. At instances where clarity was needed, the village leaders were asked to make clarifications.

2.2.2 Water sample collection

Upon identifying the water sources available to the villagers, grab water samples were collected from each source to determine the physical, chemical, and microbial quality. The water samples were obtained from two surface water sources consisting of a river and a dam and one groundwater source- an unsanitary well. The water sample was also obtained from a secondary drinking water source- package borehole water sold by water vendors. A total of 3 water samples were collected from the surface water sources. The samples were collected as composites i.e. water samples were collected from different points of the water body and mixed to form a grab sample. The water samples were obtained simultaneously (early morning) from positions where the villagers usually fetched water. At each point, the samples were collected in duplicates, based on the water quality parameters to be assessed:

i. Bacteriological samples: These samples were collected in labeled sterile plastic containers and then transported in storage containers containing ice packs to the laboratory.
ii. Physico-chemical samples: These samples were collected in clean plastic bottles. The bottles were labeled appropriately upon sample collection and then transported to the laboratory.

2.2.3 Water sample analysis

The parameter this study tested for are:

- Physico-chemical parameters: pH, Particulate Count, Total dissolved solids, electrical conductivity, Chloride, Sulphate, Calcium ion, Calcium hardness, Total Hardness, Total Alkalinity, Nitrate, Nitrite, Chromium, Lead, Iron, Zinc, Manganese. The parameters were compared with WHO and SON guidelines/standards.
- Bacteriological parameters: total coliform, *E. coli, and Salmonella* sp. The analysis was run twice- the first analysis was to detect the microbes in the raw water samples. The second was to detect the microbes in samples with a local chlorine disinfectant. The dosage used was 0.01 ml of water guard to 25ml of the water sample. A contact time of 30 minutes was ensured before the samples were analysed.

The samples were analyzed in duplicates. The parameters were compared with WHO guidelines/standards. Table 1 outlines the instruments/methods used to analyse each parameter.

2.2.4 Data management and analysis

Data from the water quality analysis were entered and analyzed using SPSS version 20. Descriptive statistics were used to determine the mean and standard deviation of each water quality parameter. Inferential statistics like ANOVA and Pearson correlation were used to evaluate differences between the quality of the groundwater sources to the quality of the surface water sources and the associations between the water quality parameters assessed, respectively. Inferential statistics were measured at a 5% level of significance.

3. RESULTS

3.1 Community Observation

Upon examining the community and observing the activities of the rural dwellers for a couple of days, it was observed that the major drinking water source was an open dam. The dam was close to their households, so the total time expended for a round trip was around 10 minutes. The same dam was used for the irrigation of farmlands located in the village.

There was no fencing around the edges of the water body; this made it possible for animals to also drink from the same source. Some ducks were noticed on the water surface around the routine water collection sites.

Plate 1. 1A shows the community's main water source; 1B shows the unsanitary well present in the community; 1C and 1D show the surface and well water's physical appearance, respectively

Table 1. Instruments and methods used for water quality analysis

Parameter	Instrument/Method
pH	Multi-parameter meter
Total dissolved solids	Multi-parameter meter
Electrical conductivity	Multi-parameter meter
Chloride	Argentomeric method
Total alkalinity	Titrimetric method
Total hardness	EDTA titration method
Calcium hardness	EDTA titration method
Sulphate	Spectrophotometric method
Nitrite	Spectrophotometric method
Nitrate	Spectrophotometric method
Chromium	
Manganese	Spectrophotometric method
Zinc	
Lead	
Iron	
E.coli	Detection via Eosin Methylene Blue (EMB)
Heterotrophic bacteria	Detection via Plate count method
Salmonella sp.	Detection via Salmonella-Shigella Agar growth medium

Furthermore, there was a shallow well situated in the village leaders' house. However, this water source was not accessible to all the villagers. This well was also quite unsanitary- it allowed for ponding around the well due to the absence of drainage, there was no apron area built around the well, the well lacked any form of fencing, and was also void of a well-cover.

Conversations with our contact person in the community gave an account of the availability of water sources throughout the year. It was reported that during the dry season, the water level of both the dam and the well in the community dropped to the base, leaving the community members with no other choice but to fetch water at an alternate water source (a river) several kilometers away. The round-trip was estimated to be about an hour, depending on the volume of the container carried. The secondary drinking water source identified was packaged water sold by vendors. However, this was not feasible for the common person due to the financial implications. The packaged water was sold for 20 Naira per 50 cL.

3.2 Water Quality Analysis

3.2.1 Physical appearance

Water samples from the surface water sources were very turbid and coloured. The water sample from the shallow well was slightly turbid with little colouration, while the packaged water was clear and colourless.

3.2.2 Physico-chemical parameters

The average pH of the groundwater was slightly acidic, while that of the surface water was neutral. All the water quality parameters were within the WHO and SON guidelines, excluding heavy metals like lead, iron, and manganese. Chromium values were at or close to 0.05 mg/L, implying the heavy metal has a probability of exceeding the permissible limit. High values of nitrite (1.22**±**1.14 mg/L) and nitrate (1.30**±**1.20 mg/L) indicated that the surface water was probably subject to faecal contamination, particularly at the river nitrate and nitrite levels were at 2.662 mg/L and 2.511 mg/L, respectively. Details about the individual parameters are present in Table 2. Table 3 classifies the water sources into ground and surface water.

3.2.3 Association between the surface water and groundwater physico-chemical quality

There were statistically significant differences between the mean pH ($p=0.020$), TDS ($p=0.006$), EC ($p=0.006$) and Zinc ($p=0.032$) concentrations of the surface water and the respective means of the groundwater. The surface water generally had higher values for all the parameters tested, indicating it was more susceptible to contamination. Details of these associations are present in Table 4.

Table 2. Physico-chemical properties of water samples from each water source

Parameters	Dam (Point 1) @ 6:30am	Dam (Point 2) @ 6:33am	River water @ 6:58am	Well water @ 7:20am	Sachet water
Turbidity	Turbid	Turbid	Turbid	Slightly Turbid	Not turbid
Odour	Unobjectionable	Unobjectionable	Unobjectionable	Unobjectionable	Unobjectionable
Colour	coloured	coloured	coloured	Slightly coloured	colourless
Particulate Count	TNC	TNC	TNC	TNC	3753
pH	7.108	7.098	7.074	6.955	6.847
T.D.S(mg/L)	88.055	80.865	79.76	55.565	59.1
EC (µS/cm)	176.11	161.73	159.52	111.13	118.2
Total Hardness(mg/L)	153.174	172.511	153.174	187.362	68.340
Calcium hardness(mg/L)	112.32	111.20	139.65	155.60	56.65
Calcium ions(mg/L)	44.928	44.88	55.86	62.24	22.66
Chloride(mg/L)	148.65	119.10	123.875	99.46	113.25
Nitrate(mg/L)	0.381	0.848	2.662	0.381	0.086
Nitrite(mg/L)	0.346	0.803	2.511	0.284	0.051
Sulphate (mg/L)	0.143	0.828	0.857	0.346	0.007
Total Alkalinity(mg/L)	155.00	135.11	120.16	120.00	55.00
Chromium (mg/L)	0.05	0.05	0.04	0.05	0.03
Lead(mg/L)	0.002*	0.168*	0.003*	0.001	0.019*
Iron(mg/L)	0.899*	1.940*	2.81*	0.574*	0.019
Manganese (mg/L)	0.675*	1.543*	3.01*	0.600*	0.015
Zinc	0.003	0.002	0.003	0.001	0.00

Values above WHO permissible limits; TNC- Too Numerous to Count

Table 3. Mean groundwater and surface water quality in comparison with WHO and SON guidelines

Parameters	Surface water Mean±SD	Groundwater Mean±SD	WHO Guideline [46,47]
pH	7.09±0.017	6.90±0.076	6.5-8.5
T.D.S(mg/L)	82.89±4.50	57.33±2.50	500
EC (µS/cm)	165.79±9.00	114.67±2.50	1000
Total Hardness(mg/L)	159.62±11.16	127.85±84.16	No guideline value
Calcium hardness(mg/L)	121.06±16.11	106.13±69.97	No guideline value
Calcium ions(mg/L)	48.56±6.33	42.45±27.99	No guideline value
Chloride(mg/L)	130.54±15.86	106.36±9.75	No guideline value
Nitrate(mg/L)	1.30±1.20	0.23±0.20	50
Nitrite(mg/L)	1.22±1.14	0.17±0.16	3.0
Sulphate (mg/L)	0.61±0.40	0.18±0.24	No guideline value
Total Alkalinity(mg/L)	136.76±17.48	87.50±45.96	No guideline

Parameters	Surface water Mean±SD	Groundwater Mean±SD	WHO Guideline [46,47]
			value
Chromium (mg/L)	0.047±0.0058	0.040±0.014	0.05
Lead(mg/L)	0.058±0.096*	0.01±0.013*	0.01
Iron(mg/L)	1.88±0.96*	0.29±0.39	No guideline value
Manganese (mg/L)	1.74±1.18*	0.31±0.41	0.4
Zinc	0.0027±0.00058	0.00050±0.00071	No guideline value

Table 4. Inferential statistics comparing mean groundwater and surface water quality parameters

Parameters	t	df	P value	95% CI
pH	4.546	3	0.020*	0.058 to 0.33
T.D.S(mg/L)	7.088	3	0.006*	14.08 to 37.04
E.C(µS/cm)	7.088	3	0.006*	28.17 to 74.08
Total Hardness(mg/L)	0.704	3	0.532	-111.86 to 175.39
Calcium hardness(mg/L)	0.385	3	0.726	-108.49 to 138.36
Calcium ions(mg/L)	0.394	3	0.720	-43.18 to 55.39
Chloride(mg/L)	1.876	3	0.157	-16.84 to 65.21
Nitrate(mg/L)	1.175	3	0.325	-1.82 to 3.94
Nitrite(mg/L)	1.231	3	0.306	-1.67 to 3.77
Sulphate (mg/L)	1.325	3	0.277	-0.61 to 1.47
Total Alkalinity(mg/L)	1.791	3	0.171	-38.28 to 136.79
Chromium (mg/L)	0.775	3	0.495	-0.021 to 0.034
Lead(mg/L)	0.666	3	0.553	-0.18 to 0.28
Iron(mg/L)	2.137	3	0.122	-0.78 to 3.95
Manganese (mg/L)	1.584	3	0.211	-1.45 to 4.32
Zinc	3.806	3	0.032*	0.00035 to 0.0040

3.3 Microbial Analysis

3.3.1 Detection of Total Heterotrophic Bacteria (THB) on nutrient agar

Coliform was detected in all the water sources. However, after the addition of a water guard, the total coliform in each sample reduced significantly. Table 5 shows details of the microbes detected across each sample.

3.3.2 Detection of *E. coli* on selective medium EMB Agar

E.coli was detected in all the water sources, with the heaviest contamination detected in the dam and the unsanitary well.

Table 5. Detection of THB in raw water and treated samples

Sample source (Raw water)	Bacterial Growth	Bacteria (CFU/mL)
Raw Dam 1	Detected (**XX**)	8.0×10^3
Raw Dam 2	Detected (**XX**)	2.2×10^3
Raw River	Detected (**XX**)	3.5×10^3
Raw Well	Detected (**XX**)	6.0×10^3
Sample source (Treated water)		
Treated Dam 1	Detected (**X**)	4.0×10^2
Treated Dam 2	Not Detected	--
Treated River	Detected (**XX**)	2.7×10^3
Treated Well	Detected (**XX**)	4.0×10^3

- ***XX-*** *Highly contaminated (above 5.0 ×10^2 CFU/mL)*
- ***X-*** *Slightly contaminated (below 5.0×10^2 CFU/mL)*

Table 6. Detection of *E. coli* in raw water samples

Sample source (Raw water)	Bacterial Growth	Bacteria
Raw Dam 1	Detected (**XX**)	Not identified
Raw Dam 2	Detected (**X**)	*E.coli*
Raw River	Detected (**X**)	*E.coli*
Raw Well	Detected (**XX**)	*E. coli*
Sample source (Treated water)		
Treated Dam 1	Detected (**X**)	Not identified
Treated Dam 2	Not Detected	--
Treated River	Not Detected	--
Treated Well	Detected (**X**)	*E.coli*

- ***XX-*** *Highly contaminated (above 5.0 ×10^2 CFU/mL)*
- ***X-*** *Slightly contaminated (below 5.0×10^2 CFU/mL)*

Table 7. Detection of *Salmonella sp.* in raw water samples

Sample source (Raw water)	Bacterial Growth	Bacteria
Raw Dam 1	Detected (**XX**)	*Salmonella sp.*
Raw Dam 2	Not Detected	--
Raw River	Detected (**XX**)	*Salmonella sp.*
Raw Well	Detected (**XX**)	*Salmonella sp.*
Sample source (Treated water)		
Treated Dam 1	Detected (**X**)	*Salmonella sp.*
Treated Dam 2	Not Detected	--
Treated River	Detected (**X**)	*Salmonella sp.*
Treated Well	Detected (**X**)	*Salmonella sp.*

- ***XX-*** *Highly contaminated (above 5.0 ×10^2 CFU/mL)*
- ***X-*** *Slightly contaminated (below 5.0×10^2 CFU/mL)*

Treatment of water samples with a water guard decimated the *E.coli* load in all the samples, excluding the well water sample, where it was reduced significantly. Moreover, the unknown bacteria grew on the EMB agar, which was not terminated by the disinfectant. Table 6 shows details of this.

3.3.3 Detection of *Salmonella sp.* on selective medium salmonella-shigella agar

Salmonella sp. was detected in all the surface and groundwater sources. Disinfection of the water samples using a water guard had no impact on the *salmonella sp*. Table 7 provides details about this.

4. DISCUSSION

The village had no water supply infrastructure; hence, the villagers depended on unimproved water sources (a dam, a river, and an unsanitary well) for their livelihood. The only drinking water available from an improved source was the packaged sachet water sold at the community's outskirts. However, because rural dwellers are typically low-income earners, this did not seem like a feasible option, leading to their dependence on unimproved sources [13-16]. The dependence of the majority of the rural dwellers in Tinda village on unimproved sources for domestic and drinking purposes due to the unavailability of basic water supply infrastructure corroborates results from other studies within the region. A survey conducted in a rural community in Northern Nigeria revealed that there were no provisions for potable water supply [11]. Another survey reported that only 0.8% of residents in Taraba (Northeastern Nigeria) had access to piped water [12]. It has also been reported that only less than 30% of households in rural settlements in Nigeria did not depend on an unimproved water supply [17,18]. Unfortunately, this leaves rural dwellers highly susceptible to waterborne diseases because most surface water sources are polluted [19- 21].

The water quality of the surface waters and the unsanitary well were unsatisfactory, as they were all turbid, only the packaged water was clear and colourless. Some other surveys have also reported the dependence of rural dwellers on sources with turbid [22,23]. However, it has been posited that drinking water's turbidity does not necessarily harm the public's health but could be a tool for risk assessment [24]. Moreover, the results of other parameters such as EC, TDS, Total Hardness, Nitrate, Nitrite, Sulphate, Total Alkalinity, Iron, Zinc, and Manganese varied based on the source of the water sample- the surface water samples generally had higher values compared to the representatives from groundwater sources. This is most definitely due to the exposure of the surface waters to more point and non-point contaminants [25,26]. Parameters like pH, TDS, EC, and Zinc had statistically significant differences (p-value<0.05) when the mean ground and surface water parameters were compared via inferential statistics. Nitrate and Nitrite values were highest in the river water sample (2.662 ppm and 2.511 ppm, respectively), suggesting the surface water was predisposed to contamination via agricultural products like fertilizers and faecal matter [27,28]. These nitrogen-based compounds' high values could potentially pose a cancer risk to consumers [29].

Furthermore, the contamination of all water samples with at least one heavy metal beyond both the WHO and a SON acceptable standard was quite bothersome. All the surface water samples had lead, iron, and manganese levels exceeding the permissible limits. For the samples from groundwater sources, the unsanitary well had iron and manganese levels beyond the acceptable standards, while the packaged water only had lead beyond the guideline values. Chromium was also detected in all the water samples at levels just at/below the acceptable limit (0.03 ppm to 0.05 ppm). Other studies in Nigeria have reported heavy metal contamination in rural surface water and groundwater sources [30-33]. Exposure to high lead has been reported to harm on the cardiovascular, immune, reproductive, endocrine, and central nervous systems [34]. Exposure to iron beyond WHO permissible limits have also been associated with conjunctivitis and neurological disorders [35]. Uptake of manganese beyond guideline values has resulted in tremors, mental imbalance, and neurological disorders [36,37]. The chromium and manganese levels in the surface waters were also above the water quality for irrigational water, suggesting that the crops being watered from these sources could uptake these heavy metals, making them unfit for consumption [38,39]. The microbial load detected in the water samples was also a cause for concern. With THB ranging from 8.0×10^3 CFU/mL to 2.2×10^3 CFU/mL and the detection of both *E.coli* and *Salmonella sp.* in the samples obtained from the river, dam, and unsanitary well, it reaffirmed the fact that none of the major water sources was fit for consumption. THB has been recommended to be less than 500 CFU/mL in potable water [40]. However, even upon treating the water samples with a water guard (a chlorine disinfectant), only the dam water was below the guideline value. The detection of *E.coli* in all the samples proved that there was recent faecal contamination around the water sources [41-43]. The consumption and usage of water contaminated with *E.coli* are unsafe because they could predispose the individuals exposed to several diarrhoeal diseases, hepatitis A and infections of the skin and eyes [39,44]. S*almonella sp* has also been reported to cause waterborne typhoid fever outbreaks when consumed [44]. Upon disinfection, the load of *E.coli* and S*almonella sp.* in the water samples reduced significantly. Turbid waters have been reported to harbor microbes, undermine disinfection processes, and even produce harmful disinfection by-products [24,45]. This suggests that depending solely on chlorine disinfection for the unimproved sources may not be effective.

5. CONCLUSION

The absence of a single improved water source within the rural community reveals we are far from achieving Sustainable Development Goals 3, 6, 10, and 11 in Nigeria. As seen from other recent surveys [48,49], inaccessibility to basic water supply also predisposes the villagers to poor sanitation and hygiene practices. Infrastructures as basic as water supply systems are integral components of every community. The villagers' dependence on unimproved water sources puts them at a constant public health risk. It is imperative for the Government to prioritize sustainable water supply systems in such rural communities to bridge the wide inequality gap in our society.

DATA AVAILABILITY STATEMENT

All relevant data are included in the paper.

CONSENT

As per international standard or university standard, respondents' written consent has been collected and preserved by the author(s).

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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