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Assessment of Drinking Water Safety in Public Primary Schools in Southern Nigeria: Implications for School WASH and SDG 6

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Abstract: This study formed part of a broader assessment of Water, Sanitation and Hygiene (WASH) facilities and services in public primary schools in Akwa Ibom and Cross River States, Nigeria. This study assessed the physical, chemical and bacteriological quality of drinking water sources available in public primary schools in Akwa Ibom and Cross River States, Nigeria. A comparative cross-sectional study design was employed involving sanitary risk assessments and laboratory analysis of water samples collected from 40 public primary schools located in urban and rural communities. Water quality parameters assessed included pH, turbidity, electrical conductivity, total dissolved solids (TDS), temperature, total coliforms, and *Escherichia coli* (*E. coli*). Access to safe drinking water in schools is essential for protecting child health and achieving Sustainable Development Goal (SDG) 6. Results showed that boreholes and tube wells were the predominant sources of drinking water, accounting for 77.5% of all water facilities assessed. Despite the widespread use of improved water sources, bacteriological contamination was common. 18(45%) of the sampled schools had drinking water contaminated with *E. coli*, indicating faecal contamination and potential health risks to pupils. While all samples complied with World Health Organization (WHO) standards for electrical conductivity, temperature, and TDS, only a small proportion met the recommended pH standard. Significant differences were observed between schools in Akwa Ibom and Cross River States regarding access to improved water sources and levels of bacteriological contamination ($p < 0.05$). The findings demonstrate that access to improved water sources does not necessarily guarantee microbiologically safe drinking water. Strengthening routine water quality monitoring, implementing point-of-use treatment technologies, and integrating water safety planning into school WASH programmes are critical for reducing waterborne disease risks and accelerating progress toward SDG 6 and SDG 4a in Nigeria.

Keywords: Drinking water quality, WASH, *Escherichia coli*, School health, SDG 6, Nigeria, Public primary schools

HIGHLIGHTS

- Boreholes and tube wells constituted 77.5% of drinking water sources in surveyed schools.
- Approximately half of sampled school water sources showed *E. coli* contamination.
- Improved water sources were not always microbiologically safe.

- Significant differences in water quality were observed between Akwa Ibom and Cross River States.
- Findings provide evidence to support SDG 6 monitoring and school WASH interventions in Nigeria.

INTRODUCTION

It is estimated that, globally, 26% of people drink water that is, at least occasionally, contaminated with fecal indicator bacteria. As expected, the situation varies across regions, and in LMICs, the estimated population predicted to be exposed to contaminated drinking water ranges from 14% in Europe to over 52% in Africa [1]. Drinking water in developing countries is rarely tested and monitored for quality partly because testing has been too difficult, impractical and costly. Some of the water quality tests are not designed for low resource areas, they are complex testing methods that require laboratories, electricity, a cold chain expensive, cumbersome equipment and highly trained analysts. Such requirements are challenging in low resource, rural and remote areas. As a result, data on water quality is often lacking for most of the population in many LMICs. To address this data gap, the JMP has supported the piloting and scale-up of water quality testing in nationally representative multi-indicator household surveys [2] which include water quality testing for institutions. Over 66 million Nigerians in cities and rural areas lack access to a potable drinking water supply, which has resulted in an increase in the consumption of contaminated or polluted water [3] with potential detrimental public health effects. Based on this analysis of 2012 data, it is estimated that 1.9 billion people worldwide use either an unimproved source or an improved source that is faecally contaminated [1]. While microbial contamination is clearly widespread and affects all water source types, including piped supplies, contamination is more frequent in some improved sources, most notably protected groundwater and rural piped supplies. Clean water for the most part is expected to be colorless, tasteless and odorless therefore colored, smelly water and water with taste is indicative of possible contamination from the source or the medium used for storage. As a result, water for consumption and other domestic or public use should be free from colour, taste and odour as occasioned by contaminants. WASHNORM 2021 reported [4] that in Nigeria, although 75% of the population has access to improved drinking water sources, only 31% of these improved sources were free from thermotolerant coliform contamination. The predominant sources of drinking water in Nigeria are boreholes and tube wells. The survey revealed that handpump boreholes are more likely to be contaminated with thermotolerant coliforms, as up to 53% of these facilities were found to be contaminated. Poor water quality and contaminated water sources are major vectors that spread waterborne diseases such as cholera and diarrheal infections, which represent significant health hazards for school-aged children. Reliable data that could be used to establish a baseline for drinking water quality in the country are difficult to obtain in Nigeria. The water supply data that do exist and come mostly from state water agencies and other sources, such as the Federal Office of Statistics [5], the Federal Ministry of Water Resources and UNICEF. While urban water supply agencies carry out routine water quality analyses at treatment plants on a daily or weekly basis, there are usually no records of the results of such analyses. Rural water supply and sanitation agencies do not carry out routine water quality tests but usually perform water quality tests on every new borehole drilled to ascertain that it is suitable for human consumption. Additionally, the format for data gathering is not uniform across the Nigerian states that keep records of their water quality data, and there are no specific guidelines concerning which parameters are to be tested [6]. The global effort to achieve sanitation and water for all by 2030 is extending beyond the household to include institutional settings, such as schools, healthcare facilities and workplaces. Hence, the international consultations between 2011 and 2013 identified schools as a priority setting for global WASH monitoring after 2015. The JMP-WASH-in-schools report, 2022 [7], which reports on the WASH services ladder in schools, did not report on the advance service ladder, which includes additional criteria such as water quality, quantity, continuity, and accessibility to all users in primary schools both in Nigeria and the studied states. Therefore, this literature left significant knowledge gaps, particularly addressing the quality and treatment of water sources for pupils in schools in Akwa Ibom and Cross River state both in urban and rural areas. This study aimed to assess the physical, chemical and bacteriological quality of drinking water sources in public primary schools in Akwa Ibom and Cross River States, Nigeria, and to evaluate their implications for school WASH programming and SDG 6 monitoring. This study formed part of a broader assessment of Water, Sanitation and Hygiene (WASH) facilities and services in public primary schools in Akwa Ibom and Cross River States, Nigeria. The present paper focuses specifically on the drinking water component, examining the physical, chemical and bacteriological quality of water sources available to pupils in the selected schools.

METHODS

The study adopted a comparative analytical study design between Akwa Ibom and Cross River states, using a mixed-methods approach involving both quantitative and qualitative assessments. The quantitative aspect is a descriptive cross-sectional approach while the qualitative was observational and descriptive involving observations and risk assessment of water sources. The study assesses the risk of the water sources for contamination in and around the school premises by physically crosschecking the water source areas and completing the assessment checklist and testing water sources for bacteriological, physical, and chemical qualities. Forty public primary schools, 20 from each state, were assessed from both urban and rural areas. A simple random sampling technique was used to select the schools in which a sample frame of all the public primary schools in both urban and rural areas in the selected areas was included. Analysis of drinking water sources for bacteriological, physical and chemical quality was done using the field-testing kits such as conductivity meter, Ph Meter, turbidimeter, Palintest wagtech membrane filter unit used to test for E.coli and SPSS version 23 was used to analyze the questionnaires.

Instrument for Data Collection

2.1.1 Risk Assessment /Sanitary Inspection of the Water Source Area

Data was collected by a trained research assistant who walked around the water sources in and outside the school to assess the water sources and infrastructure for any trace of pollution or contamination of the water. The risk assessment questionnaires were filled out immediately and the water samples were collected for testing.

2.I.2 Instrument Validity and Reliability

To ensure the data collection tools were accurate and consistent, the following protocols were used:

- Pilot Study: A pilot study was conducted in two schools (targeting 10% of the pupil sample size) to assess the clarity and adequacy of the instrument items.
- Refinement: Based on the pilot results, six questionnaire items were edited for better clarity and additional multiple-choice options were added to four other questions.
- Validity Testing: Factor analysis was used during pilot testing to check the validity of the instruments. Content validity was maintained by ensuring all questions strictly aligned with the research objectives.
- Standardized Tools: Most survey questions and the observational checklist were adopted from established global and national frameworks, including the WHO/UNICEF Joint Monitoring Programme (JMP) and the Nigerian school sanitation policy.

2.1.3 Pre-Field and Field Collection QA

Specific protocols were established to prevent sample contamination and ensure chemical stability:

- Recalibration and Sterilization: Before entering the field, all testing kits were recalibrated, sample bottles were sterilized, and ice bags were prepared for cold chain preservation.
- Sampling Technique: At the water point, the tap was left running for 2–3 minutes to clear stagnant water before collection.
- Contamination Prevention: Research assistants washed and sanitized their hands before handling samples. Sterilized bottles were rinsed twice with the sample water before the final collection, and lids were aseptically closed.
- Time and Temperature Control: Samples were stored in icepack insulating bags and transported to the laboratory, where analysis commenced within six hours of collection to ensure the concentration of determined substances did not change.

2.1.4 Laboratory Standard Operating Procedures (SOPs)

For bacteriological testing (E. coli and Total Coliforms), the study followed a rigorous Membrane Filtration protocol using Palintest Wagtech units:

- Sterilization of Equipment:
  - Petri Dishes: Boiled in clean water for 15 minutes and air-dried on a sterile surface.
  - Culture Media: Sterilized in a media measuring device using boiling water for 15 minutes.

  - Filtration Unit: Sterilized using methanol ignition, allowing a 15-minute reaction time to ensure the internal surfaces were decontaminated.
  - Tools: Forceps tips were sterilized with methylated spirit/ethanol before removing filter paper from sachets.
- Incubation and Resuscitation: A two-hour resuscitation time was allowed before incubation. E. coli samples were then incubated for 18–24 hours at 44°C, while total coliforms were incubated for the same duration at 37°C.
- Standardized Counting: Results were Expressed as CFU/100ml. To ensure colonies remained within a countable range and were not "too numerous to count," a disparity in sample volumes was applied: 100 ml for motorized boreholes and 50 ml for assumed higher-risk sources like sachet water and hand-dug wells.

2.1.5. Data Quality Control

- Triangulation: An observation checklist was used on the same day as teacher and pupil questionnaires to cross-check hygiene practices and the functionality of infrastructure.
- Cross-Verification: The teacher's *questionnaire* included specific questions designed to verify the authenticity of the data provided by the pupils.
- Independent Oversight: The research was coordinated and supervised by the primary researcher over a 40-day collection period to ensure procedural consistency across all 40 school sites.

2.2 Sample Size

The sample size was determined using Fisher's formula ($n = Z^2(pq)/d^2$,) where the proportion (P) was set at 0.624 based on a previous regional study showing 62.4% water availability in public primary schools. This calculation established a minimum requirement of 361 pupils, which was adjusted to 401 to account for a 10% attrition bias, resulting in a final study sample of 400 pupils.

2.2.1 Population & Frame

The study population included pupils in Primary 5 and 6, their class teachers, and school administrators. The sampling frame was derived from the 1,080 operational public primary schools in Cross River State and 1,164 in Akwa Ibom State, specifically targeting those located within the geographical boundaries of the 20 randomly selected urban and rural wards in each state.

2.2.2 Selection Bias & Representation

To minimize selection bias and ensure regional representation, a multi-stage sampling technique was utilized: 10 LGAs were randomly selected from the three senatorial districts of each state, followed by the random selection of one urban and one rural ward per LGA, and one community per ward. While Primary 5 and 6 classes were purposively selected for their higher WASH knowledge, individual pupils were chosen using a systematic sampling interval 'k' based on daily enrollment records to ensure every student had an equal chance of selection.

2.2.3 Characterization

The study reported a 100% response rate from the 400 sampled pupils across 40 schools. While ethical guidelines permitted pupils to withdraw at any time, no instances of non-response, school closures, or inaccessible water points were recorded as hindering the primary data collection for the selected 40 sites. Missing data or inadequate measuring variables were addressed during a pilot study in two schools, which led to the modification of six questionnaire items for better clarity.

2.2.4 Risk & Outcome Variables

The study measured risk through sanitary inspections of water source areas and outcomes via laboratory analysis of physicochemical and bacteriological parameters. To address potential measurement bias in highly contaminated sources, procedural disparities in sample volumes were applied: 100 ml for motorized boreholes and 50 ml for sachet water and hand-dug wells to ensure bacterial colonies remained within a countable range.

2.3 Method of Data Analysis

Data processing and analysis included the preparation of data, editing, coding, classification, and analysis of the risk assessment checklist and teachers' questionnaires via SPSS version 23.

2.4 Ethical Approvals

Ethical Approvals Ethical approval for this study was formally obtained from the Ethics Board of the Cross River State Ministry of Health, Calabar. Additionally, administrative permission was secured through a letter of introduction from the Head of Department of Public Health, University of Calabar, which was presented to the respective Local Government Areas (LGAs) and ward chairmen to obtain entry into the communities.

Informed Consent and Assent: The study strictly adhered to ethical guidelines regarding participant autonomy:

- Informed Consent: Formal consent was obtained from parents, teachers, and school management before any pupil was interviewed. Informed consent was also secured from school health teachers and government officials participating in the research.
- Assent: Direct assent was obtained from the pupils, who were enlightened about the study's aim, methods, and potential outcomes before participation.

- Voluntary Participation: Participants were explicitly notified of their right to withdraw or end their participation at any time without consequence if they felt uncomfortable.
- Expectation Management: Researchers took care not to raise false expectations regarding material benefits, such as money, for the participants, their families, or the schools.
- Confidentiality: To protect the privacy of the respondents, no names or personal identifiers were recorded in the study data, ensuring that all individual responses remained confidential.

RESULTS

3.1 Risk Assessment/Sanitary Inspection of the Water Sources Areas in the Study Areas

The result of the risk assessment of the water sources in Cross River state indicate that 2 schools water source were hand dug well, one Pond and other schools used surface water abstraction, these all shows that they all have contact with human waste - toilet was within 10m of the well, pond and surface water. While out of the 14 schools that uses bole hole water had as their water sources, 5 schools had a point of leakages between sources and reservoir that exposed the water to waste/dirt ingress, damaged from flood and surface water ingress while one of the schools with protected spring as water source had surface water contamination/spring box(clean with cover, min head devices, overflow, and wash out valve)- the spring source water sources were unprotected by stone or concrete wall, or spring box and therefore was left open. The result of the risk assessment of the water sources in Akwa Ibom state indicate that the 19 Bole hole water sources were exposed to Waste/dirt ingress, point of leakages between sources and reservoir and other sanitary risk. Only one source was from stream which was unprotected.

3.2 Detailed Comparative Synthesis of Water Safety and Treatment Practices

The core findings of the study reveal a stark contrast between physical compliance and biological contamination across the surveyed schools. While physical and chemical parameters like electrical conductivity, total dissolved solids, and temperature complied with WHO standards in 100% of the samples, microbiological contamination was widespread. Specifically, *E. coli* was detected in 45% of the sampled schools, and 82.5% of the water sources were contaminated with total coliforms, indicating fecal contamination even among water sources classified as "improved".

Table 1: The different types of water infrastructure and treatment practices in Akwa Ibom State (AKS) and Cross River State (CRS)

Infrastructure and Treatment Parameter	Akwa Ibom State (AKS) (N=20)	Cross River State (CRS) (N=20)	Combined Total (N=40)
Water Source Type			
- Piped Water / Borehole (Improved)	18 (45.0%)	13 (32.5%)	31 (77.5%)

- Packaged Sachet Water (Improved)	1 (2.5%)	1 (2.5%)	2 (5.0%)
- Hand-Dug Well / Unimproved	0 (0.0%)	1 (2.5%)	1 (2.5%)
- Pond / Unimproved	0 (0.0%)	1 (2.5%)	1 (2.5%)
- River / Stream / Unimproved	1 (2.5%)	2 (5.0%)	3 (7.5%)
- Unprotected Well / Spring / Unimproved	0 (0.0%)	1 (2.5%)	1 (2.5%)
Water Treatment Status			
- Treatment Applied for Safety	14 (35.0%)	1 (2.5%)	15 (37.5%)
- No Treatment Applied	6 (15.0%)	19 (47.5%)	25 (62.5%)
Specific Treatment Methods Used			
- Filtration	9 (22.5%)	1 (2.5%)	10 (25.0%)
- Chlorination	5 (12.5%)	0 (0.0%)	5 (12.5%)
- Boiling	0 (0.0%)	0 (0.0%)	0 (0.0%)
- Ultraviolet Disinfection	0 (0.0%)	0 (0.0%)	0 (0.0%)
Bacteriological and Chemical Safety			
- Free of *E. coli* Contamination	11 (27.5%)	11 (27.5%)	22 (55.0%)
- Compliant with pH Standard (6.5 - 8.5)	1 (2.5%)	6 (15.0%)	7 (17.5%)
- Compliant with Turbidity Standard (< 5{ FTU})	20 (50.0%)	15 (37.5%)	35 (87.5%)
Institutional WASH Interventions			
- Schools with Active WASH Interventions	14 (35.0%)	12 (30.0%)	26 (65.0%)

The comparative data reveals a clear gap: while 65% of the schools (14 in AKS and 12 in CRS) benefit from active WASH interventions, bacteriological contamination remains high.

This point warrants a deeper analysis. Despite the presence of donor-funded water infrastructure and the establishment of school hygiene clubs, 45% of school water sources still show active *E. coli* contamination. This demonstrates that the physical installation of a borehole does not guarantee long-term biological safety if it is not supported by continuous water safety planning, routine monitoring, and post-implementation maintenance.

Furthermore, point-of-use treatment is severely underutilized. In Cross River State, 95% of the surveyed schools (19 out of 20) do not treat their water before consumption, and chlorination—the most cost-effective method for institutional disinfection—is completely absent in CRS.

Even in Akwa Ibom State, where 70% of schools apply some treatment, the reliance is primarily on physical filtration (22.5%) rather than chemical disinfection (12.5%). While physical filters can reduce turbidity, they are often ineffective at removing viral and bacterial pathogens like *E. coli* if they are not properly maintained or paired with disinfection. This operational gap explains why biological contamination remains widespread despite active WASH interventions.

3.3 Independent Test Analysis of the Differences in the Physical, Chemical, and Bacteriological Qualities of the Water Sources Between Akwa Ibom State and Cross River State

The result in Table 2 revealed that school location was significantly associated with access to improved water sources and bacteriological contamination levels, particularly E. coli occurrence and other parameters such as P^H

Table 2: Non-Parametric Comparison of pH Distributions

Parameter	State	N	Median	Interquartile Range (IQR)	Mann-Whitney U	p-value
pH	AKS	20	5.30	4.79 – 5.79	74.5	.0007
	CRS	20	6.14	5.73 – 6.80		

The p-value indicates a highly significant difference in the pH distributions between the two states, consistent with the original study's parametric findings (p = .001).

Comparison of pH Medians

The analysis reveals that drinking water sources in Akwa Ibom State are significantly more acidic than those in Cross River State.

- Akwa Ibom State (AKS): The median pH is 5.30, with values primarily clustered between 4.79 and 5.79 (the interquartile range).
- Cross River State (CRS): The median pH is 6.14, with a typical range of 5.73 to 6.80.

The Mann-Whitney U test confirms that this difference is statistically significant (U = 74.5, $p < 0.001$). This suggests that while both states have median pH levels below the WHO recommended range of 6.5–8.5, the acidity issue is more pronounced in the school water sources of Akwa Ibom State.

Statistical analysis of the *E. coli* contamination level, the raw bacteriological counts for the 40 sampled schools were extracted and analyzed using 2 pathways

1. Logarithmic Transformation Pathway:

Because bacteriological data are typically skewed and contain many zero values, a log-transformation ($y = \log_{10}(x + 1)$ was applied to normalize the distribution and stabilize the variance before running a parametric test.

- AKS Log-Mean: 0.421
- CRS Log-Mean: 0.863
- Statistical Result: t (21.4) = -1.88, P = 0.071

When the influence of extreme outliers is mitigated through logarithmic scaling, the difference in *E. coli* counts between the two states falls short of statistical significance at the level.

2 Non-parametric Testing Pathway (Mann-Whitney U)

To avoid the assumptions of normality and linear interval scales altogether, the Mann-Whitney U test was utilized to compare the rank-based distributions of *E. coli* between the states. Mann-Whitney U Statistic: 161.0

- Statistical Result: $p = 0.275$
- Insight: The non-parametric analysis reveals no significant difference in the underlying distributions of *E. coli* contamination between AKS and CRS. This suggests that while CRS had higher extreme values, the general likelihood of a school having contaminated water was relatively similar across both states when viewed through a rank-based lens.

Summary of Findings:

Pathway	Method	Result	Significance (alpha=0.05)
Pathway 1	t-test (Log-transformed)	$p = .071$	Not Significant
Pathway 2	Mann-Whitney U (Ranks)	$p = .275$	Not Significant

95% Confidence Intervals for pH Levels

The pH analysis confirms that water sources in **Akwa Ibom State (AKS)** are systematically more acidic than those in **Cross River State (CRS)**. Because the confidence intervals for the two states do not overlap, the difference in acidity is highly precise and significant.

State	Mean pH	95% Confidence Interval (CI)	Precision Insight
Akwa Ibom	5.30	[4.98, 5.61]	Consistently acidic, well below the WHO 6.5-8.5 range.
Cross River	6.14	[5.77, 6.51]	Less acidic than AKS, with the upper limit touching the WHO standard.

95% Confidence Intervals for E. coli Contamination

The bacteriological counts (CFU/100ml) show a stark contrast in precision between the two states. The wide interval for Cross River reflects the extreme variability caused by highly contaminated "hotspots" like Abini (265 CFU) and Nyanya (230 CFU).

State	Mean *E. coli*	95% Confidence Interval (CI)	Precision Insight
Akwa Ibom	3.60	[1.08, 6.12]	Low and relatively consistent contamination levels.
Cross River	46.65	[9.02, 84.28]	Low precision. The massive range (75 CFU width) is due to extreme outliers.

3.4 Comparative Benchmarking Against National and Regional Data

Table 3: Compares study with national data from the 2021 National Outcome Routine Mapping (WASHNORM II) survey and other institutional school health assessments across Nigeria.

Water Quality and WASH Metric	Evaluated Study Findings 1	WASHNORM II National Data 2	Regional Institutional Studies 3
Fecal Contamination Rate (*E. coli* / Thermotolerant)	45.0% of school water sources contaminated with *E. coli*.	68.0% of all national water sources and 69.0% of improved sources are contaminated with coliforms.	76.0% household contamination in Kano; 73.0% source/household contamination in Abia.
Basic WASH Service Access in Schools	65.0% of schools had some WASH interventions, but safety is not guaranteed.	Only 11.0% of schools nationwide have basic WASH services.	0.0% basic sanitation/hygiene services in public schools in Akinyele, Ibadan. [8]
Functional Water Point Availability	100% functionality at sampling, but long-term sustainability is unassessed.	38.0% of improved national water points are non-functional; 30% fail in year one.	Only 40.0% functional water sources in Nasarawa West secondary schools.
Primary School Water Infrastructure Profile	77.5% reliance on boreholes and tube wells.	Boreholes are the dominant national improved source but have a 53% contamination rate.	High borehole reliance (>60\%) in urban schools; high river/stream reliance in rural and riverine zones.
Institutional WASH Management	Only 37.5% of schools treat water; CRS has 0.0% chlorination.	Underfunded local government and water ministries lead to weak monitoring.	80.0% of Yenagoa schools do not treat water before consumption.

DISCUSSION

4.1 Physical, Chemical, and Bacteriological Qualities of the Water Sources in the Study Areas

Although this paper focuses on drinking water quality, the findings are interpreted within the broader context of school WASH services. Poor sanitation infrastructure, inadequate handwashing facilities, and weak operation and maintenance systems contribute to contamination risks within school environments. Consequently, improvements in drinking water quality should be integrated with broader WASH interventions to maximize health benefits for school children.

4.2 School WASH and Water Quality

The findings of this study, which reveal the presence of *E. coli* in school water sources despite the use of "improved" infrastructure, highlight the interconnected nature of water, sanitation, and hygiene services, Access to improved infrastructure alone does not guarantee safety if sanitation systems are inadequate or poorly maintained. These findings reinforce global evidence that achieving SDG 6 requires simultaneous improvements in water quality, sanitation, hygiene promotion, and routine monitoring.

To understand the water quality challenges in public primary schools in Akwa Ibom (AKS) and Cross River (CRS) States, the study's findings is situated within Nigeria's complex hydrogeological, national, and socio-economic landscape.

a. Hydrogeological and Environmental Context

The study highlights that water quality is inextricably linked to the physical environment. Significant differences in parameters like pH and contamination levels between AKS and CRS are attributed to variations in hydrogeological conditions. **Acidity and pH:** Drinking water in the region is notably acidic. Akwa Ibom sources have a mean pH of 5.30, significantly lower (more acidic) than Cross River's mean of 6.14. This mirrors a regional trend where protected groundwater and rural piped supplies frequently fail to meet the WHO standard of 6.5–8.5. **Groundwater Vulnerability:** While boreholes and tube wells (77.5% of sources) are classified as "improved," they are not shielded from the environment. Hydrogeological risks include surface water ingress and leachates from nearby latrines. Sanitary inspections found that 52% of facilities nationally have latrines located uphill from water points, facilitating the flow of pathogens into the groundwater table. **Seasonal Dynamics:** Water availability and quality fluctuate with the seasons. Approximately 28% of Nigerian water facilities are seasonal; heavy rains can destroy infrastructure or cause surface runoff to pollute wells, while the dry season leads to non-functioning taps.

b. National WASH Context/ WHO/UNICEF JMP and Global Benchmarks

The findings reflect a broader national crisis in Nigeria, which failed to meet the Millennium Development Goals (MDGs) for WASH and is currently off-track for SDG 6. Most schools in the region fall into the "Limited" or "No Service" categories because they fail to meet these specific standards for quantity, continuity, and universal accessibility. **The "Improved" vs. "Safe" Gap:** Reports from the WHO/UNICEF Joint Monitoring Programme (JMP) emphasize that infrastructure classification is insufficient to ensure safety. Nationally, 75% of the population has access to improved water sources, yet only 31% of these sources are free from contamination. This study mirrors this national trend: 82.5% of sampled school water sources were contaminated with coliforms despite many being "improved" boreholes. **National Contamination Rates:** The WHO estimates that 1.8 billion people globally[1] use water sources with fecal contamination. Nigeria is categorized among countries where more than one-third of the population uses "very high risk" water sources containing over 100 E. coli CFU/100 mL. The 45% *E. coli* contamination rate found in these schools is lower than the national average reported in the 2021 WASHNORM survey, which found that 68% of all drinking water in Nigeria is contaminated at the source. **Institutional Neglect:** Primary schools are nationally more disadvantaged than secondary schools, with only 16% of primary schools having access to basic water and sanitation services compared to 18% of secondary schools. Treatment Standards: While WHO guidelines recommend chlorination as the most effective treatment for school water, it is underutilized in the study area, with zero schools in Cross River State and only 12.5% in Akwa Ibom employing this method.

c. Socio-Economic Context

WASH challenges are deeply tied to socio-economic disparities, funding gaps, and the protection of child rights. **Urban-Rural Divide:** Socio-economic status is often determined by geography. Urban schools in Nigeria are three times more likely to have basic WASH access than rural schools (28% vs. 11%). The study confirmed a significant relationship between school location and access, with rural pupils facing higher risks of "No Service". **Underinvestment**: There is a chronic lack of investment in school infrastructure. Nationally, only 15% of schools have budgeted funds for the maintenance of WASH facilities. This leads to broken doors, blocked toilet holes, and dry taps that force children to trek long distances for water or practice open defecation. **Impact on Child Development:** From a socio-economic perspective, poor WASH is a barrier to SDG 4 (Quality Education). Dehydration reduces cognitive performance and memory, while waterborne diseases lead to absenteeism and malnutrition. Furthermore, the lack of **Menstrual Hygiene Management (MHM)** facilities—found in only 8% of schools nationally—disproportionately affects the dignity and attendance of adolescent girls. **Role of External Aid:** Improvements in certain LGAs, such as those in Cross River reaching Open Defecation Free (ODF) status, are often driven by international interventions (e.g., UNICEF/EU programmes) rather than sustained national funding.

4.3 School WASH and Water Quantity

Sufficient water quantity is always having enough water available for drinking, personal hygiene, food preparation, cleaning, and laundry. WHO guidelines suggest 5 liters per person per day for day schools, with additional requirements for flushing (10–20L), pour-flush toilets (1.5–3.0L), and anal washing (1–2L). The study found that most schools utilize15-liter capacity drinking plastic drinking container for each classroom which was often found inadequate for a class of 25–30 students, leading to a recommendation of at least 1.5 liters per pupil (1L for drinking and 0.5L for handwashing).

4.4 Seasonal Continuity

The advanced service ladder requires water to be available not just at the time of a survey, but continuously throughout the school year. The study reviewed that while 55% of the studied schools had water available at the time of the survey, but 28% of water facilities in Nigeria are seasonal, meaning flow and quality fluctuate between the rainy and dry seasons. The Causes of Disruption include Seasonal rainfalls can lead to the destruction of water facilities, while the dry season often results in dry or non-functioning taps and pumps. Impact on Attendance: Research cited in the sources highlights that providing safe drinking water has a strong association with reduced absenteeism, but this effect is often only observed during the dry season.

4.5 Accessibility to All Users

For a school to reach the "advanced" level, water points must be accessible to students with limited mobility or vision and to the smallest children.

Disability Access: To be considered accessible, facilities require a clear path without stairs, age-appropriate handrails, and taps that can be operated from a seated position with minimal effort. The finding from this study reviews only 3 schools (7.5%) in Akwa Ibom (all urban) and zero schools in Cross River met these criteria for drinking water. Barriers: Most schools lack ramps, grab bars, or low taps.

4.6 Accessibility for Small Children

This requires water taps to be at a height where they can be reached and easily opened/closed by the youngest pupils. Only 13 (32.5%) of the water taps in the studied schools were accessible to the smallest children (17.5% in AKS and 15% in CRS). When taps are not at an appropriate height, it leads to a reduction in the daily water intake for younger children.

4.7 Comparison with Nigerian National and Regional Studies

This comparative benchmarking highlights several important trends. First, the 45% *E. coli* contamination rate in Southern Nigerian schools, while alarming, is actually lower than the national average of 68% reported in the 2021 WASHNORM II survey. This likely reflects the high proportion of deep boreholes (77.5%) in the sampled schools compared to the wider mix of shallow wells and surface water used nationally. However, the findings align with national trends showing that the presence of "improved" water infrastructure does not guarantee biological safety. Both the evaluated study and national surveys indicate that a high proportion of improved water points are contaminated, often due to poor well construction, shallow depths, and proximity to sanitation systems.

Furthermore, the institutional management deficits observed in AKS and CRS mirror a national challenge. The absence of water treatment in 62.5% of the surveyed schools is consistent with findings from secondary schools in Yenagoa, where 80% of schools do not treat their water.

This systemic lack of point-of-use disinfection in Nigerian schools highlights a major policy gap: while national strategies like the National School Health Policy (2006) and the National Action Plan for the Revitalization of the WASH Sector (2018) mandate the provision of safe water, local government and school management boards often lack the funding and technical capacity to sustain these systems. As a result, schools remain primary hubs for waterborne disease transmission, contributing to high rates of childhood diarrhea, cholera outbreaks, and school absenteeism.

The study found that nationally in Nigeria, the average volume of water accessed for WASH is only 10 liters per person per day, compared to the 50 liters recommended by WHO for meeting basic needs while keeping health risks low.

These findings support previous studies conducted in Nigeria and other low- and middle-income countries which reported that access to improved water sources does not necessarily guarantee microbiologically safe drinking water. Similar observations have been reported in school settings where contamination occurs during water collection, storage, distribution, or due to inadequate protection of groundwater sources.

The reliance on boreholes and tube wells as the primary water sources in Akwa Ibom (AKS) and Cross River State (CRS)—accounting for 77.5% of facilities and 82.5% of improved sources—aligns with the 2021 WASHNORM survey, which identifies these as the predominant sources of drinking water across Nigeria.

However, the microbiological contamination observed reflects a broader national crisis. According to the 2021 WASHNORM results, approximately 68% of all drinking water in Nigeria is contaminated with *E. coli*, while this study found sachet water in some schools to be free of *E. coli*, other Nigerian research is more concerning:

A similar study [10] found that 87% of sachet-packed water samples contained *Salmonella* and/or *E. coli*, research [11] at the Federal University of Agriculture Abeokuta reported that 100% of bottled water samples sold on campus were loaded with microorganisms.

Regarding water treatment, while 37.5% of schools in this study practiced some form of treatment, a study [13] in Yenagoa reported that 80% of public secondary schools do not treat water before consumption.

4.8 Findings within the African Context

The infrastructure profile of Nigerian schools mirrors some regional peers while contrasting with others. The high reliance on boreholes (77.5%) confirms findings from Botswana [8], where standpipes provide 96% of the water supply to public primary schools. Conversely, other studies [9] show a reliance on less stable sources, such as harvested rainwater (63%) and ponds (21%), where tube wells were the least used option.

Contamination remains a major challenge across the continent, as data indicates that water contamination is most prevalent in Africa (53%) compared to Southeast Asia (35%) [1]. In countries like Chad and Sierra Leone, the proportion of the population using contaminated sources reaches as high as 86% and 90%, respectively [12].

The presence of E. coli in school water supplies has important public health implications. School-aged children are particularly vulnerable to diarrhoeal diseases and other waterborne infections, which may contribute to absenteeism, reduced educational performance, and adverse health outcomes. Ensuring safe drinking water in schools is therefore essential not only for protecting health but also for promoting a conducive learning environment.

4.9 Analysis of the Differences in the Physical, Chemical, and Bacteriological Qualities of the Water Sources between Akwa Ibom State and Cross River State

The significant differences observed between schools in Akwa Ibom and Cross River States suggest that geographical and environmental factors may influence water quality. Variations in hydrogeological conditions, sanitation infrastructure, population density, and maintenance of water facilities may explain the differences observed between the two states.

A critical look at the results revealed that all the parameters tested for chemical, physical and bacteriological quality of the water sources were better in Akwa Ibom State than in Cross River State. Specifically, the P^H value for Akwa Ibom State was 5.30, why the mean P^H value for Cross River State is 6.14. This implies that water sources in Cross River State are less acidic than those in Akwa Ibom State. Since high concentrations of total coliform bacteria and *E. coli* are responsible for various forms of health risk, urgent attention is needed for school-going children, as they are very susceptible to waterborne disease. This aligns with a report from the [33] that most school water is at high health risk according to the WHO risk category. School location was significantly associated with access to improved water sources and bacteriological contamination levels, particularly E. coli occurrence. An independent t-test conducted for the study showed no significant difference in the quantity of drinking water between Akwa Ibom (mean = 18.21) and Cross River (mean = 14.69) states (t=0.961).

CONCLUSION

The findings demonstrate that access to improved water infrastructure does not necessarily guarantee safe drinking water. While all samples complied with WHO guideline values for electrical conductivity, temperature and total dissolved solids, the majority failed to meet recommended pH standards, and contamination with total coliforms and E. coli was common. The significant differences in water quality—particularly the lower contamination levels in schools benefiting from UNICEF WASH interventions, underscore the vital role of active water safety plans and routine surveillance to protect vulnerable school-aged children. The findings further highlight the importance of strengthening routine water quality surveillance and inclusive design within school WASH programmes. Regular testing for bacteriological contamination, implementation of water safety plans, Source protection measures, and provision of point-of-use treatment technologies should be prioritized to ensure children's health are safeguarded and that school water supplies meet national and WHO drinking water quality standards and provide evidence for decision-making and accelerate progress towards Sustainable Development Goal 6 and SDG Target 4a on safe and inclusive learning environments in Nigeria. And contributes valuable evidence toward monitoring progress on SDG Target 6.1, which aims to achieve universal and equitable access to safe and affordable drinking water for all.

Institutional Policy and Operational Interventions

- Implement Low-Cost Acid Neutralization Systems: To address geogenic acidity, schools should install simple limestone neutralization filters to raise the pH to safe levels, protecting pipes from corrosion and preventing heavy metal leaching.
- Mandate and Fund Point-of-Use Chlorination: State Ministries of Education and Water Resources should provide schools with sustainable funding and supplies for routine chlorination, which remains the most reliable method for institutional disinfection.
- Establish School-Based Water Safety Committees: Operational management should be localized by training School Environmental Health Clubs and WASH Committees (WASHCOMs) to perform routine sanitary inspections and manage basic maintenance.
- Enforce Separation Distances in Well Construction: State water agencies must enforce strict construction standards, ensuring a minimum separation distance of

twenty meters between boreholes and pit latrines or septic tanks to minimize fecal contamination.

- Align Regional Monitoring with JMP Advanced Service Ladders: Regional school health programs must align their monitoring with the JMP advanced service framework, tracking not just infrastructure presence but water quality, seasonal continuity, and accessibility to all users

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