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RESEARCH ARTICLE

ASSESSMENT OF THE PHYSICOCHEMICAL AND BACTERIOLOGICAL QUALITY OF DRINKING WATER FROM CEMENTED WELLS AND MINI DRINKING-WATER SUPPLY SYSTEMS IN AWARIDI VILLAGE, DIFFA, NIGER

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Abstract

Drinking-water quality is a critical determinant of public health, particularly where groundwater is the main source of supply. This study assessed the physicochemical and bacteriological quality of water from five drinking-water facilities in Awaridi village, Diffa, Niger: two cemented wells (PC1 and PC2), two boreholes (F1 and F2), and one mini drinking-water supply system (Mini-AEP). One analytical observation per facility is reported (n=5). Physicochemical parameters were measured in situ and in the laboratory using the procedures described in Rodier et al. (2009) and spectrophotometric methods, while bacteriological analyses used membrane filtration of 100 mL samples. The measured physicochemical values were generally within the comparison values used in this study (pH 6.65–7.88; electrical conductivity 316–449 $\mu\text{S}/\text{cm}$; total hardness 40–192 mg/L as CaCO_3). In contrast, bacteriological contamination was detected in the sampled facilities: total coliforms ranged from 0 to 200 CFU/100 mL (mean 94 CFU/100 mL) and fecal coliforms from 50 to 150 CFU/100 mL (mean 98 CFU/100 mL). Using the Nigerien reference criteria for wells and boreholes, 80% of the observations were non-compliant for total coliforms and 100% for fecal coliforms.

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The first two PCA axes explained 72.56% of the variance and mainly separated mineralization-related variables from coliform-related variables. Because only five facilities were assessed, the correlation, PCA, and hierarchical cluster analyses are considered exploratory and are not used to establish causal relationships or village-wide prevalence. The findings support continued sanitary surveillance, protection of water points, and repeated sampling across seasons in Awaridi village.

Introduction: -

Water is fundamental to life, human well-being, food security, and socioeconomic development. Safe drinking water is essential for preventing water-related diseases and supporting resilient communities. Drinking-water quality is therefore a major public health and environmental concern. International guidelines emphasize a risk-based approach to protecting water safety from the source to consumption (Théophile and Albert, 2023; Talhaoui et al., 2020; WHO, 2022). This need is increasingly important because population growth, urbanization, rising water demand, and environmental pressures affect both water availability and quality (Vörösmarty et al., 2010; IPCC, 2022).

Globally, access to a water source does not necessarily guarantee access to safe drinking water. In 2022, approximately 2.2 billion people lacked safely managed drinking-water services, while at least 1.7 billion used sources contaminated with feces (WHO/UNICEF, 2023; WHO, 2023). Unsafe water, sanitation, and hygiene remain important contributors to preventable diseases, particularly diarrhoeal diseases, especially in low- and middle-income countries (WHO, 2023a; Bain et al., 2014a; Bain et al., 2014b). Consequently, regular assessment of drinking-water quality is essential for identifying contamination risks and protecting vulnerable populations.

Groundwater is a major source of domestic water supply, particularly in rural and peri-urban areas. It provides approximately half of the volume of water withdrawn for domestic use globally and is particularly important where centralized water-supply systems are limited (UN-Water, 2023; UNESCO, 2022). In Africa, groundwater provides relatively reliable access to water under variable climatic conditions; however, its quality and vulnerability depend on hydrogeological characteristics, recharge processes, land use, and abstraction practices (MacDonald et al., 2012; Mac Donald and Calow, 2009). Increasing water demand and climate change further reinforce the need for groundwater protection and systematic monitoring (IPCC, 2022; Vörösmarty et al., 2010).

Despite natural filtration during infiltration, groundwater is not intrinsically safe. Shallow wells, inadequately protected boreholes, and small water-supply systems may be contaminated by latrines, wastewater, solid waste, agricultural activities, runoff, and poor sanitary management. Evidence from low- and middle-income countries shows that improved water sources may still contain fecal contamination, including protected wells (Bain et al., 2014a). Similar contamination has been reported in African wells and boreholes, particularly where sanitation and source protection are inadequate (Lutterodt et al., 2018). African water-supply systems also face challenges related to infrastructure, treatment capacity, operation and maintenance, governance, and water-quality surveillance (Wang et al., 2014). Household treatment and safe storage can reduce microbial risks, but source protection and regular surveillance remain essential (Sobsey, 2002; WHO, 2022).

These challenges are particularly important in the Sahel, where groundwater is a strategic resource under arid and semi-arid climatic conditions. Studies in Niger have reported variations in the physicochemical and bacteriological quality of drinking-water sources according to water-source type, hydrogeological conditions, and sanitary environment. In western Niger, Adamou et al. (2020) identified differences in water quality among wells, boreholes, and small drinking-water supply systems, with bacteriological contamination affecting several sources. In Niamey, groundwater contamination has also been associated with inadequate sanitation and infiltration from polluted superficial layers (Chippaux et al., 2002). Recent research in the Komadugu-Yobe Basin highlights the importance of groundwater-quality assessment for sustainable water-resource management in the Sahel (Shuaibu et al., 2024). In northern Niger, contamination by uranium, fluoride, and nitrate further demonstrates the potential for both geogenic and anthropogenic groundwater-quality risks (Alhassane et al., 2026). Similar microbial contamination problems have been reported in other African countries, including Ghana and Nigeria (Lutterodt et al., 2018; Owamah et al., 2021).

In Niger, these challenges are compounded by disparities in water infrastructure, limited monitoring capacity, climatic variability, and dependence on groundwater sources. Safe drinking-water management therefore requires an integrated assessment of physicochemical and microbiological quality, together with consideration of sanitary

vulnerability and relationships among water-quality parameters (WHO, 2022). Water quantity, accessibility, reliability, and quality are also interconnected determinants of public health and well-being (Howard and Bartram, 2003; Howard et al., 2020). Strengthening water-quality monitoring is consequently important for climate resilience and sustainable development in water-stressed regions such as the Sahel (UNESCO, 2022; IPCC, 2022).

In the urban commune of Diffa, particularly in Awaridi village, drinking water is supplied through groundwater-based facilities, including cemented wells, boreholes, and mini drinking-water supply systems (Mini-AEP). However, localized information on their combined physicochemical and bacteriological quality remains limited. This study therefore aimed to: (i) assess the physicochemical and bacteriological quality of water from two cemented wells, two boreholes, and one Mini-AEP in Awaridi village; (ii) compare the measured values with WHO guidance and applicable Nigerien drinking-water reference criteria; and (iii) explore relationships and patterns among the measured water-quality variables. Because the study covers only five facilities, the results are interpreted as a site-specific assessment rather than a statistically representative estimate for the entire village.

Materials and Methods:-

Study area:-

The Urban Commune of Diffa is one of the three communes of the Department of Diffa, Diffa Region. It is located in south-eastern Niger on National Road No. 1, approximately 1,360 km from Niamey, the capital. The commune borders the Rural Commune of Gueskérou to the east and north and the Commune of Chétimari to the west. To the south, it borders the Federal Republic of Nigeria (Borno State) along more than 20 km marked by the Komadougou Yobe River (Fig. 1). Awaridi village is located within the urban commune and relies on groundwater-based facilities for drinking-water supply.

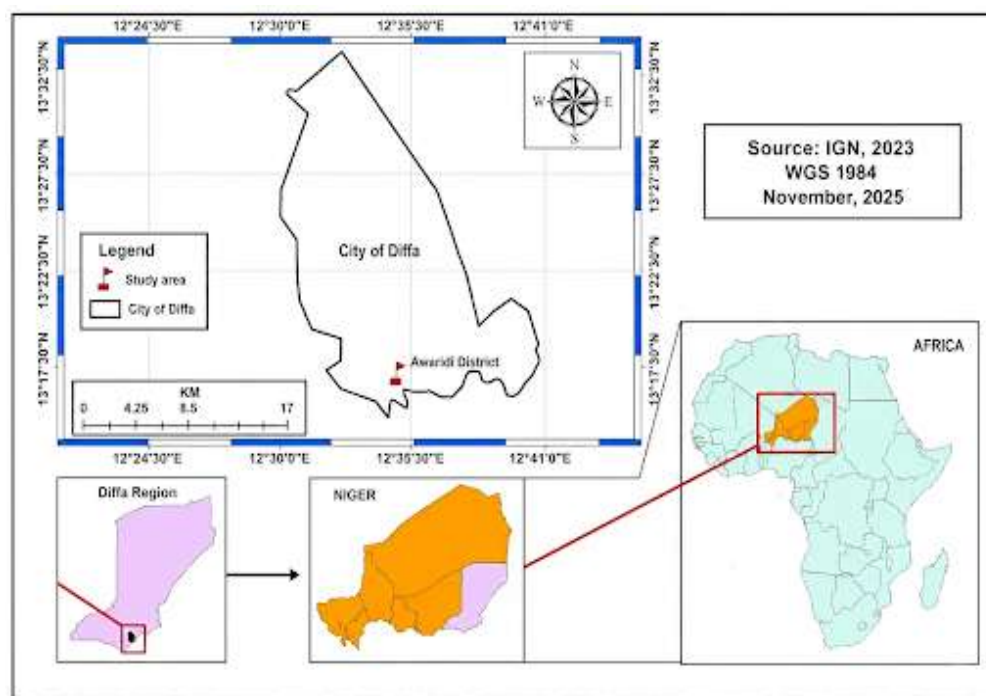


Fig. 1: Location of the study area

Sampling design and sample collection:-

The study used a cross-sectional design based on five drinking-water facilities in Awaridi village. The facilities were selected to cover the main source types used in the study area: two cemented wells (PC1 and PC2), two boreholes (F1 and F2), and one Mini-AEP. The analytical dataset contains one observation per facility ($n=5$); therefore, the five facilities, rather than individual households, are the sampling units. The available manuscript records do not document repeated sampling across seasons, so seasonal variability cannot be assessed. Likewise, the study was not

designed to provide a statistically representative estimate of water quality for the entire village. The facility codes used throughout the Results section are PC1, PC2, F1, F2, and Mini-AEP.

Physicochemical and bacteriological analysis methods:-

Table 1 summarizes the analytical procedures, materials, reagents, and conditions reported for the sampled waters. Physicochemical measurements were performed in situ and in the laboratory. Microbiological analyses used membrane filtration of 100 mL of water, followed by incubation on the culture medium used in the laboratory procedure. Sterilized sampling bottles, sterile gloves, an autoclave, a filtration ramp, 0.45- μ m membrane filters, and an incubator were reported among the materials used. The term “atypical coliforms” is retained as a laboratory-reported category; because the available analytical documentation does not provide a validated taxonomic definition for this category, it is not assigned a specific sanitary or causal interpretation in this manuscript.

Table 1 :Analytical methods and materials for the sampled waters

Analytical method	Principle description /	Parameters	Materials reagents /	Reference conditions /
Physical measurement	Direct measurement of physical parameters	pH, conductivity, temperature	pH meter, conductivity meter	In situ measurement
Chemical analysis	Determination of major cations and anions according to the standardized Rodier method.	Ca ²⁺ , Mg ²⁺ , K ⁺ , Na ⁺ , NO ₂ ⁻ , NO ₃ ⁻ , Cl ⁻ , SO ₄ ²⁻ , Fe	- Specific chemical reagent for each ion; - Sterilized sampling bottles; - Laboratory glassware	Rodier et al. (2009)
Spectrophotometric method	Quantitative analysis by molecular absorption spectrophotometry	Fe, K ⁺ , SO ₄ ²⁻ , F ⁻ , NO ₃ ⁻ , NO ₂ ⁻	- Hach spectrophotometer; - WAGTECH/7100 photometer; - specific reagents; - sterilized sampling bottles; - laboratory glassware	Laboratory spectrophotometry; wavelengths as reported in the original analytical protocol
Ion balance calculation method	Calculation of sodium from ionic balance (sum of cations = sum of anions).	Na ⁺	Formula: $\frac{[Na^+]}{23} = \frac{([Cl^-] + [SO_4^{2-}] + [NO_3^-] + [HCO_3^-]) - ([Ca^{2+}] + [Mg^{2+}] + [K^+])}{2}$	Rodier (2009) In laboratory
Volumetric methods	Titration to determine ion concentrations.	Ca ²⁺ , Mg ²⁺ , Cl ⁻ , TAC, TH	EDTA, Claver, Na hydroxide, Manver, mercuric nitrate, diphenyl carbazone, sulfuric acid, bromocresol	Calcium hardness: $Ca = D_{cal} \times 0,4$; $TH = EDTA \times 4 \times 800/20$; $mg = (TH - D_{cal}) \times 0,243$ In laboratory
Bacteriological method	Membrane filtration of 100 mL of sample followed by incubation and colony enumeration.	Total coliforms, fecal coliforms, atypical coliforms	- AquaSafe MSL50; - membrane filtration unit; - Petri dishes and agar media; - autoclave; - incubator; - 0.45- μ m filters; - distilled water; - sterile gloves	Incubation: 37 °C for 18 h for total coliforms; 44 °C for 24 h for fecal coliforms

Statistical analyses and mapping:-

XLSTAT version 2018 was used to calculate descriptive statistics (minimum, maximum, median, and mean), Spearman rank correlations, and principal component analysis (PCA). Minitab 19 was used for hierarchical cluster analysis (HCA), and ArcMap 10.8 was used to prepare the maps. Each statistical analysis was based on the five facility-level observations. Given the very small sample size ($n=5$) relative to the number of measured variables, Spearman correlations, PCA, and HCA were treated as exploratory descriptive analyses. No statistical significance or causal relationship is inferred from the correlation coefficients or multivariate groupings, and the results should not be generalized beyond the sampled facilities.

Results and Discussion:-**Physicochemical quality:-**

The physicochemical measurements from the five sampled facilities are summarized in Table 2. The pH ranged from 6.65 to 7.88 (mean 7.53), which is within the WHO comparison range of 6.5–8.5 and the Nigerien reference range reported for drinking water. Water temperature ranged from 25 to 28 °C, with a mean of 26.8 °C. The Nigerien standard identifies 25 °C as a desirable temperature; this value is not interpreted here as a health-based limit. Electrical conductivity ranged from 316 to 449 $\mu\text{S}/\text{cm}$, indicating relatively low mineralization within the sampled facilities; no health-based WHO guideline value is assigned to EC in the cited drinking-water guidance. Total hardness ranged from 40 to 192 mg/L as CaCO_3 (mean 112.8 mg/L), but hardness is not treated as a health-based compliance criterion in this analysis. Chloride (4.30–9.20 mg/L), sulfate (11–52 mg/L), nitrate (0.54–1.80 mg/L), nitrite (0.01–0.15 mg/L), and iron (0.020–0.260 mg/L) were below the comparison values used for these parameters. Calcium (14.40–49.60 mg/L) and magnesium (0.971–24 mg/L) were also below the corresponding Nigerien reference ranges. These results support the conclusion that no measured physicochemical parameter exceeded the comparison criteria used in this study. However, physicochemical compliance alone does not establish microbiological safety. The results are broadly comparable with observations reported for groundwater and drinking-water sources in Niger and neighbouring West African settings (Bachir et al., 2021; Adamou et al., 2020; Dan et al., 2018). Differences among studies should nevertheless be interpreted in relation to source type, sampling design, season, analytical methods, and the reference standards applied.

Table 2: Physicochemical quality of water from the five sampled facilities.

Parameters	pH	Temperature	EC	TH	HC O_3^-	Cl^-	SO_4^{2-}	NO_3^-	NO_2^-	K^+	Fe	Ca^{2+}	Mg^{2+}
Unit	-	°C	$\mu\text{S}/\text{cm}$	mg/L as CaCO_3	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
N	5	5	5	5	5	5	5	5	5	5	5	5	5
Minimum	6.65	25	316	40	66.37	4.30	11	0.540	0.01	3.10	0.020	14.40	0.971
Maximum	7.88	28	449	192	195.20	9.20	52	1.800	0.15	7.40	0.260	49.60	24
Median	7.71	27.80	324	120	136.64	6.80	25	0.800	0.11	4.10	0.100	38.40	3.880
Mean	7.53	26.80	362.8	112.8	136.25	6.96	28.4	1.004	0.10	4.72	0.116	35.52	9.462
WHO guideline/reference	6.5–8.5	—	—	—	—	250	—	50	3	—	0.3	—	—

Nigerien reference	6.5 – 9.2	25 (desirable)	—	—	—	250	200	45	—	—	0.3	75–200	50–150
% non-compliance	0	/	/	/	/	0	0	0	0	/	0	0	0

Note: “—” indicates that no comparison value is assigned in the cited sources for this analysis. The 25 °C temperature value in the Nigerien standard is a desirable value, not a health-based limit. Percent non-compliance is calculated only for parameters with an explicit comparison criterion.

Bacteriological quality:-

Bacteriological results indicate that microbial quality is the main concern in the sampled facilities (Table 3). Total coliforms ranged from 0 to 200 CFU/100 mL, with a mean of 94 CFU/100 mL. Four of the five observations exceeded the Nigerien reference criterion reported for wells and boreholes, corresponding to 80% non-compliance. Fecal coliforms ranged from 50 to 150 CFU/100 mL, with a mean of 98 CFU/100 mL; all five observations exceeded the Nigerien criterion of 0 CFU/100 mL, corresponding to 100% non-compliance. WHO drinking-water guidance uses *Escherichia coli* or thermotolerant coliforms as the principal verification indicators and requires them to be not detectable in a 100-mL sample; the present study measured fecal coliforms and therefore does not equate the result directly with *E. coli*. Comparisons with studies from Cameroon and Ghana also indicate that fecal contamination of groundwater is a recurring concern in settings with inadequate source protection (Biguioh et al., 2020; Akrong and Banu, 2017). However, the present data do not identify the contamination pathway. Possible mechanisms such as inadequate sanitary protection, wastewater infiltration, or runoff require direct sanitary inspection or source-tracking evidence and therefore are not treated as demonstrated causes here. The microbiological results nevertheless indicate that the sampled facilities require strengthened sanitary surveillance and, where appropriate, treatment before direct consumption.

Table 3: Bacteriological quality of water from the five sampled facilities.

Parameters	Total coliforms	Atypical coliforms	Fecal coliforms
Unit	CFU/100 mL	CFU/100 mL	CFU/100 mL
N	5	5	5
Minimum	0	6	50
Maximum	200	70	150
Median	80	20	90
WHO reference	—	—	0 CFU/100 mL*
Nigerien reference (wells/boreholes)	<10 CFU/100 mL	—	0 CFU/100 mL
% non-compliance	80	/	100

Note: Bacteriological results are reported as CFU/100 mL because the analytical procedure used membrane filtration of 100 mL of water. The “atypical coliforms” category is reported descriptively and is not used as a direct drinking-water compliance indicator.

Figure 2 shows the relative contribution of each sampled facility to the total number of total-coliform colonies measured across the five facility-level observations. The displayed percentages (PC1 43%, PC2 32%, Mini-AEP 17%, F2 9%, and F1 0%) should be interpreted as relative shares of the observed total-coliform counts, not as prevalence, probability of contamination, or non-compliance rates. The figure therefore illustrates differences among the five sampled facilities but does not establish a causal explanation for those differences.

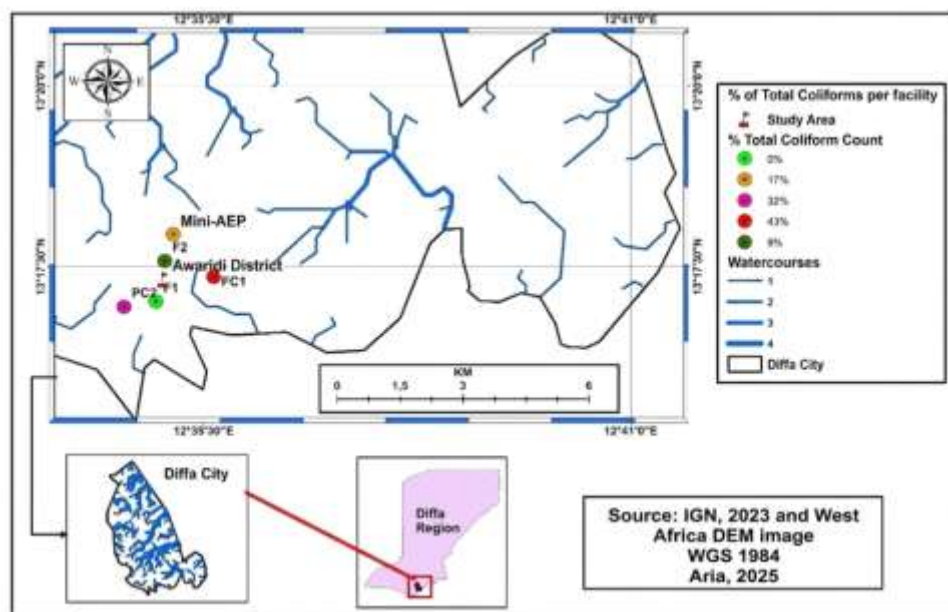


Fig. 2: Relative share (%) of total-coliform counts among the five sampled facilities.

Figure 3 shows the corresponding relative shares of atypical-coliform counts, ranging from 4% to 51% among the facilities. F2 contributes the largest share (51%), whereas the Mini-AEP contributes the smallest share (4%). Because the study contains only one observation per facility and the atypical-coliform category is not independently defined in the available laboratory documentation, these differences are reported descriptively and are not interpreted as evidence of a technical failure, aquifer pollution, or better sanitary protection.

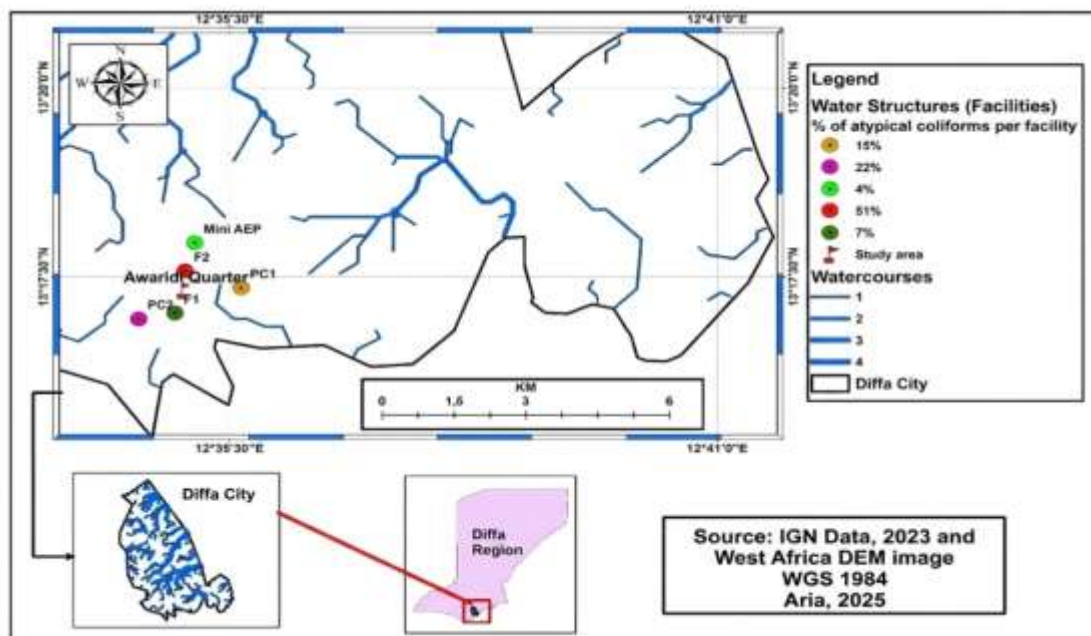


Fig. 3: Relative share (%) of atypical-coliform counts among the five sampled facilities.

Figure 4 shows the relative shares of fecal-coliform counts across the five sampled facilities. PC1 and PC2 each account for 31% of the observed fecal-coliform count, F1 accounts for 18%, and F2 and the Mini-AEP each account for 10%. These percentages describe the distribution of the observed counts among the five facilities; they should

not be interpreted as contamination prevalence or as proof of a particular pollution source. The results support the need for facility-specific sanitary inspection and repeated microbiological monitoring.

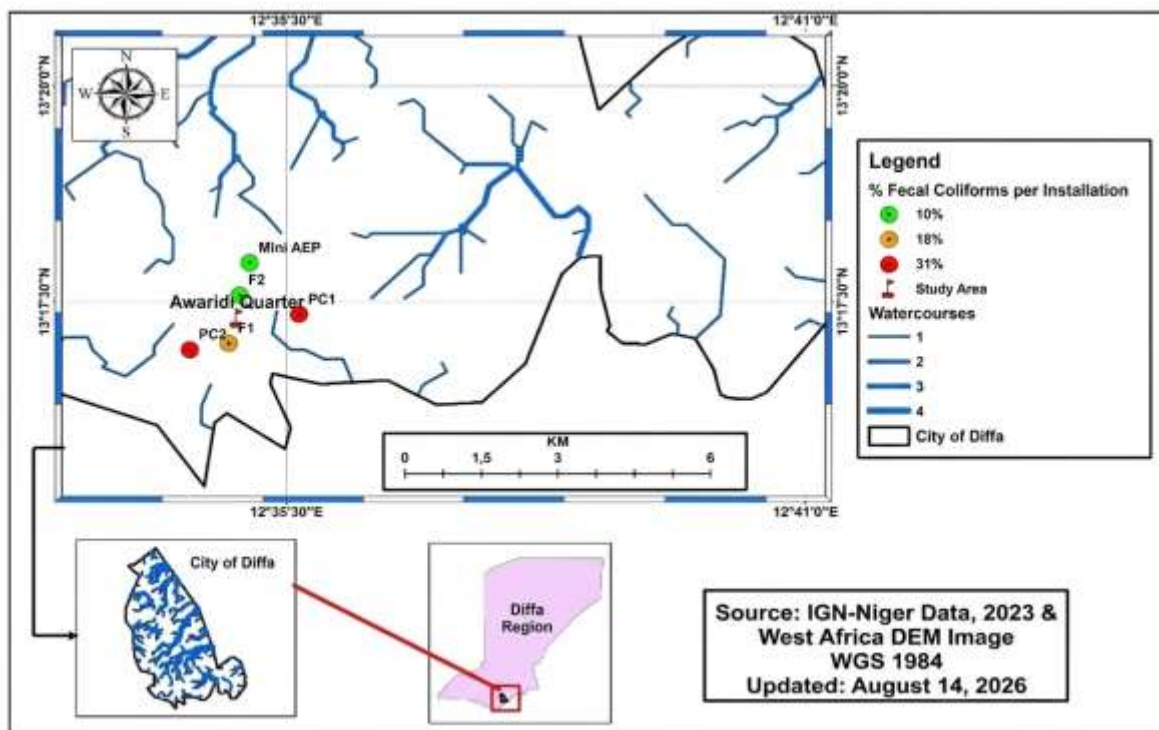


Fig. 4: Relative share (%) of fecal-coliform counts among the five sampled facilities.

Spearman correlation and principal component analysis:-

The Spearman correlation matrix (Table 4) describes the pairwise relationships among the measured physicochemical and bacteriological variables. Several high absolute correlation coefficients are present, including the relationships of total hardness with calcium ($\rho=1.000$), total hardness with bicarbonate ($\rho=0.900$), electrical conductivity with bicarbonate ($\rho=0.800$), and sulfate with chloride ($\rho=0.900$). These coefficients are consistent with shared variation among mineralization-related variables in the five observations. However, because $n=5$, the coefficients are highly sensitive to individual observations, and no statistical significance is claimed. The correlation matrix should therefore be regarded as exploratory rather than inferential. Among the microbiological variables, atypical coliforms showed a high positive association with temperature ($\rho=0.872$), while fecal coliforms showed a positive association with pH ($\rho=0.791$). These associations describe the present five-observation dataset only. They do not demonstrate that temperature promotes bacterial growth, that pH causes fecal-coliform persistence, or that iron suppresses bacterial proliferation. Such mechanisms would require controlled experiments, repeated sampling, or additional environmental measurements.

Table 2: Spearman correlation matrix of physicochemical and bacteriological parameters

Variables	pH	Temperature	EC	TH	HCO ₃ ⁻	Cl ⁻	SO ₄ ²⁻	NO ₃ ⁻	NO ₂ ⁻	K ⁺	Fe	Ca ²⁺	Mg ²⁺	TC*	AC*	FC*
pH	1															
Temperature	0.564	1														
EC	0.200	0.359	1													
TH	0.100	0.564	0.500	1												

HCO ₃ ⁻	0.00 0	0.462	0.80 0	0.90 0	1											
Cl ⁻	0.10 0	-0.051	- 0.10 0	- 0.80 0	- 0.60 0	1										
SO ₄ ²⁻	- 0.30 0	-0.410	- 0.30 0	- 0.90 0	- 0.70 0	0.90 0	1									
NO ₃ ⁻	- 0.50 0	0.308	- 0.30 0	0.10 0	0.00 0	0.10 0	0.20 0	1								
NO ₂ ⁻	- 0.56 4	0.000	- 0.56 4	- 0.66 7	- 0.82 1	- 0.56 4	- 0.41 0	0.20 5	1							
K ⁺	- 0.30 0	-0.821	- 0.30 0	- 0.90 0	- 0.70 0	0.60 0	0.80 0	0.30 0	0.35 9	1						
Fe	- 0.10 0	-0.205	- 0.90 0	- 0.70 0	- 0.90 0	0.50 0	0.60 0	0.40 0	0.71 8	0.40 0	1					
Ca ²⁺	0.10 0	0.564	0.50 0	1.00 0	0.90 0	- 0.80 0	- 0.90 0	0.10 0	0.66 7	0.90 0	0.70 0	1				
Mg ²⁺	0.10 0	0.205	0.90 0	0.70 0	0.90 0	- 0.50 0	- 0.60 0	0.40 0	0.71 8	0.40 0	1.00 0	0.70 0	1			
TC*	0.10 0	-0.205	0.50 0	- 0.50 0	- 0.10 0	0.70 0	0.60 0	0.40 0	0.10 3	0.60 0	0.20 0	0.50 0	0.20 0	1		
AC*	0.30 0	0.872	0.70 0	0.60 0	0.70 0	0.00 0	0.30 0	0.30 0	0.35 9	0.70 0	0.50 0	0.60 0	0.50 0	0.10 0	1	
FC*	0.79 1	0.162	0.47 4	- 0.15 8	0.00 0	0.31 6	0.00 0	0.79 1	0.40 6	0.15 8	0.31 6	0.15 8	0.31 6	0.63 2	0.15 8	1
* TC: total coliforms; AC: atypical coliforms; FC: fecal coliforms.																

A principal component analysis was used to summarize the multivariate structure of the five facility-level observations. The first two axes explain 72.56% of the variance (49.80% on F1 and 22.76% on F2). In the correlation circle (Fig. 5), F1 is mainly associated with mineralization-related variables, including total hardness, calcium, bicarbonate, electrical conductivity, and magnesium, while F2 is more strongly associated with the coliform variables and pH. The PCA is interpreted only as an exploratory description of the observed pattern because the analysis is based on five observations and many variables. The percentage of variance explained should not be interpreted as evidence that the underlying processes have been established or that the pattern is stable across the village or across seasons. The general pattern is comparable with multivariate water-quality studies in Niger and neighboring regions, although differences in sample size and measured variables limit direct comparison (Amadou et al., 2014; Maoudombaye et al., 2023).

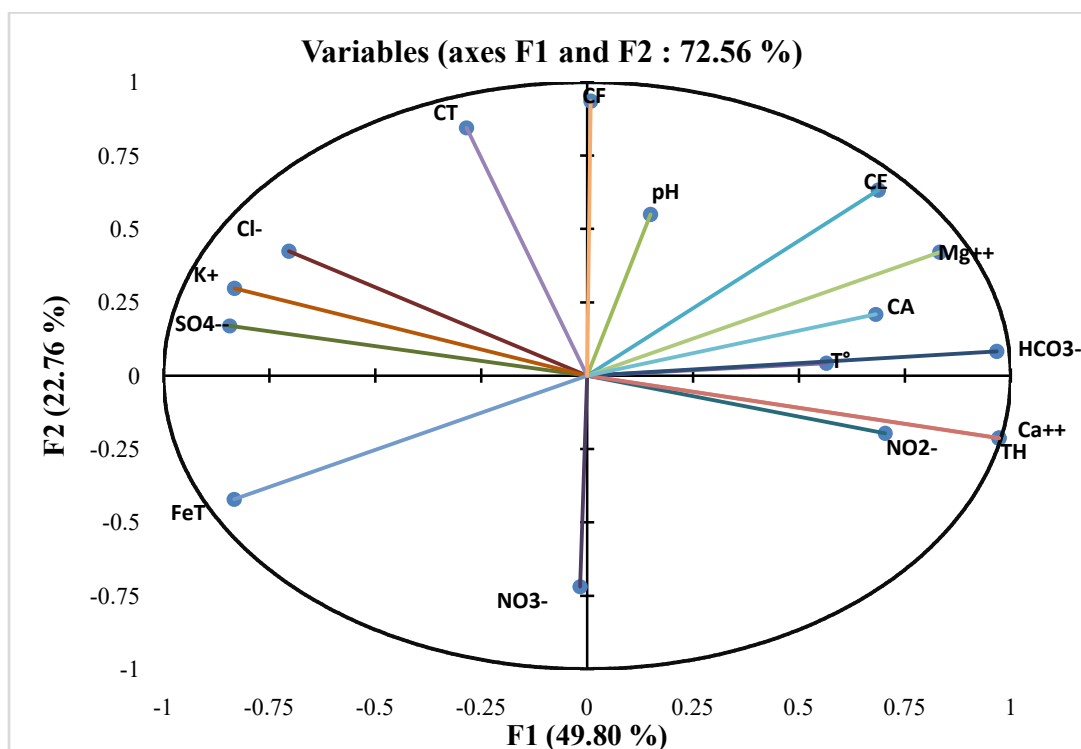


Fig. 5: Correlation circle of physicochemical and bacteriological parameters.

The projection of the five facilities onto the factorial plane (Fig. 6) indicates that F1 and F2 are positioned toward mineralization-related variables, whereas PC1 and PC2 are positioned closer to the coliform-related variables. The Mini-AEP is located on the opposite side of F1 from most mineralization variables. These positions represent statistical similarities within the five sampled observations. They may suggest differences among source types, but they do not demonstrate that geological dissolution, wastewater infiltration, poor maintenance, or sanitary protection caused the observed patterns.

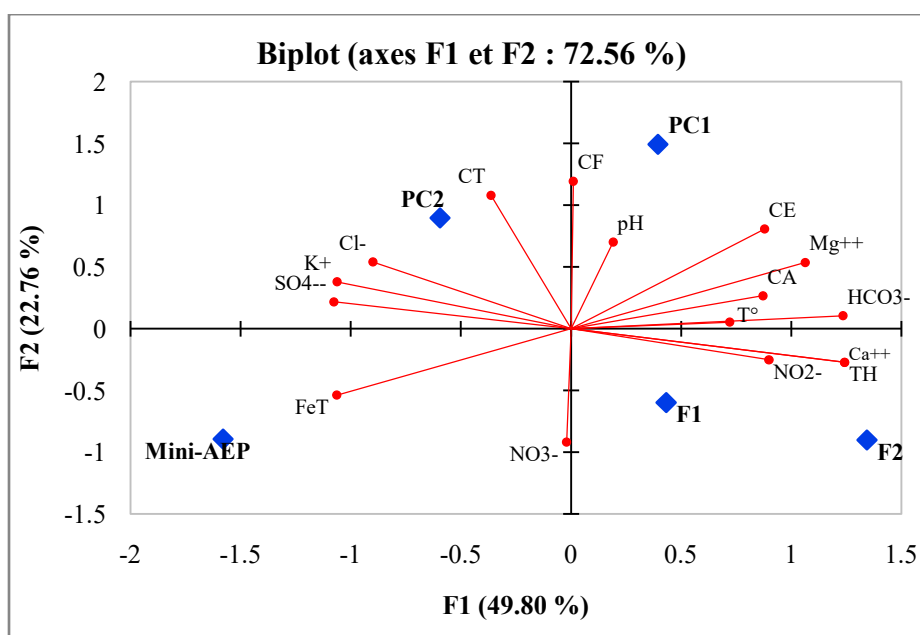


Fig. 6: PCA biplot of physicochemical and bacteriological parameters and the five sampled facilities.

Hierarchical cluster analysis:-

The hierarchical cluster analysis (Fig. 7) was performed using Ward's method with distance based on the absolute correlation coefficient. Three groups of variables are visible in the dendrogram. One group contains pH, Fe, temperature, K^+ , Cl^- , SO_4^{2-} , and Ca^{2+} ; a second contains EC, Mg^{2+} , TH, HCO_3^- , and atypical coliforms; and a third contains NO_3^- , NO_2^- , fecal coliforms, and total coliforms. These groups indicate statistical similarity in the five-observation dataset. They should not be interpreted as evidence that the variables have a common pollution source or that anthropogenic contamination has been demonstrated. In particular, grouping nitrate, nitrite, and coliform variables does not by itself establish a shared source such as latrines, soak-away pits, or runoff. Similar multivariate groupings have been reported in other groundwater studies, but direct comparison remains limited by differences in sample size, variables, and analytical methods (Amadou et al., 2014).

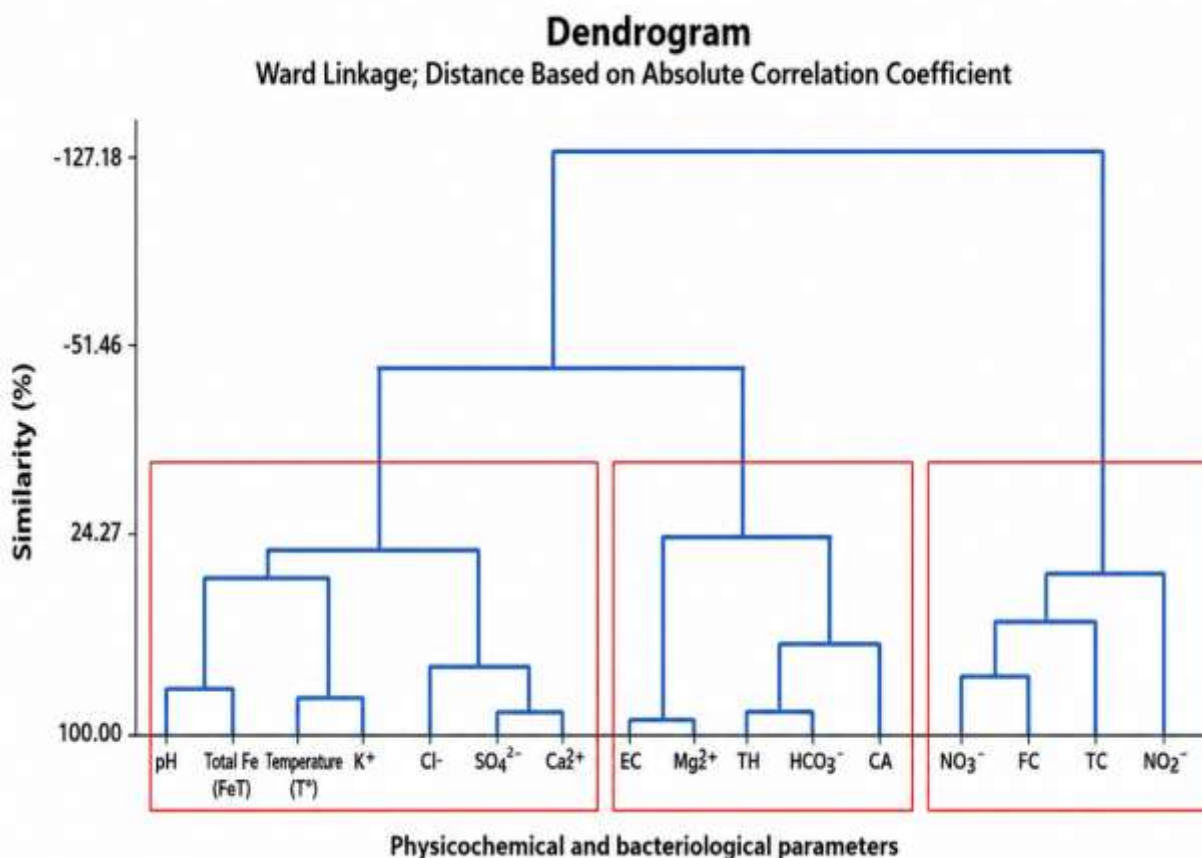


Fig. 7: Hierarchical clustering of physicochemical and bacteriological parameters.

Study limitations and management implications:-

This study has four principal limitations. First, only five facilities were assessed, so the results cannot be generalized to all water points or households in Awaridi village. Second, the dataset contains one analytical observation per facility, which prevents estimation of temporal variability and limits the robustness of correlation, PCA, and cluster analyses. Third, the available study documentation does not provide repeated seasonal sampling, detailed sanitary-inspection scores, direct source-tracking data, exact sampling dates/season, or detailed laboratory quality-control and instrument-calibration records; consequently, temporal variability and proposed contamination pathways cannot be confirmed, and no unsupported methodological details have been added. Fourth, future investigations should strengthen microbiological verification using clearly defined indicators such as *Escherichia coli* or thermotolerant coliforms. Future work should therefore include repeated sampling across dry and rainy seasons, a larger number of facilities, sanitary inspections around each water point, documented sampling dates, transport and laboratory quality-control procedures, and confirmatory microbiological analyses. For management, priority should be given to routine microbiological surveillance, protection and maintenance of water points, sanitary inspection of wells and boreholes, and appropriate treatment of water that fails microbiological criteria.

Conclusion:-

The assessment of five drinking-water facilities in Awaridi village showed generally acceptable physicochemical characteristics within the comparison criteria used in this study, with pH values of 6.65–7.88, relatively low electrical conductivity, and no measured exceedance of the selected physicochemical reference values. The main water-quality concern was microbiological: total coliforms exceeded the Nigerien reference criterion in 80% of the facility-level observations, while fecal coliforms exceeded the criterion in 100% of observations. The PCA and hierarchical clustering analyses identified exploratory patterns separating mineralization-related variables from coliform-related variables, but these multivariate results should be interpreted cautiously because only five facilities were sampled. The study does not establish the causes of contamination and does not support village-wide prevalence estimates. The findings nevertheless justify strengthened sanitary inspection, routine microbiological monitoring, protection and maintenance of water points, and repeated sampling across seasons. Facilities that remain microbiologically non-compliant should receive appropriate treatment or corrective measures before water is consumed directly.

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Disclosure of conflict of interest:-

The authors declare no conflicts of interest regarding this manuscript.

Ethical approval:-

Ethical approval was not required because the study involved environmental water samples and did not involve human participants, personal data, clinical procedures, or experimental intervention.

Informed consent:-

Not applicable. No human participants were enrolled, and no personal or household-level information was collected.

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