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Assessment of Bacteriological Quality and Physico-Chemical Parameters of Freshwater and the Associated Risk Factors in Gombe State, Nigeria

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Abstract

This study presents a comprehensive assessment of the bacteriological quality and physicochemical parameters of freshwater sources in Gombe State, Nigeria, and evaluates the associated public health, environmental, and economic risks. Water samples were collected from seven strategic locations across six Local Government Areas, encompassing four major dams and three rivers. Bacteriological analysis was conducted using the Most Probable Number (MPN) method to quantify total coliform and Escherichia coli levels. Physicochemical parameters, including pH, temperature, turbidity, total dissolved solids (TDS), dissolved oxygen, heavy metals, nitrate, and ammonia, were analyzed following standard American Public Health Association (APHA) protocols. The sampling sites exceeding the World Health Organization (WHO) standard of 0 CFU/100ml for both total coliforms (700–3500 CFU/100ml) and *E. coli* (300–2400 CFU/100ml), indicating widespread faecal pollution. Key physicochemical parameters such as turbidity (48–1098 NTU) and temperature (26–33°C) also significantly surpassed WHO guidelines. Elevated levels of chromium and nitrate were detected, further indicating pollution from industrial and agricultural sources. The primary pollution sources were agricultural runoff, domestic and urban wastewater, with associated risks encompassing waterborne disease outbreaks. The freshwater resources in Gombe State are critically polluted and pose a significant threat to public health and sustainable development.

Keywords: Water Quality, Faecal Pollution, Bacteriological Assessment, Physico-chemical Parameters, Waterborne Diseases,

Introduction

Fresh surface waters, including dams, rivers and streams, serve for drinking, domestic, agricultural, recreational, industrial and other purposes including transportation and hydroelectricity (Chigor *et al*. , 2012). However, these waters are vulnerable to pollution (Azizullah, *et al*., 2011; Chigor *et al*. , 2012), and are continually being impacted on, as a result of rapid population growths, land development along river basin, agriculture, urbanization and industrialization that place increased demand on surface waters both as sources of water for different uses and as disposal channels for treated/untreated wastewaters (Suthar *et al*., 2010; Solaraj *et al*., 2010).

Most of our fresh waters have been contaminated by natural processes, and human activities in several ways. Commonly observed in our water bodies are suspended solids, oxygen demanding materials, dissolved inorganic compounds (particularly compounds of phosphorus and nitrogen) and harmful/pathogenic bacteria. Wastes from water can also contain chemicals which are toxic to both aquatic life and man, some having insidious harmful effects at all levels of food chain (Tchounwon *et al*. , 2012). Many researchers recognized water as a medium for transmission of enteric bacteria, which in effect reduces the quality of water in many communities.

Water is very essential for the survival and sustenance of life yet, 844 million people worldwide still lacked even a basic drinking water service. As a result, 159 million people still collect drinking water directly from surface water sources, of which 58% lives in sub – Sahara Africa (WHO/UNICEF, 2017). Such water bodies are susceptible to faecal contamination of human and animal origins thereby becoming of poor microbial quality and are often contaminated by pathogens, leading to outbreaks of water – borne infections and related diseases (Chigor, *et al*., 2013; Pandey *et al.*, 2014; King –Abia *et al.,* 2017). An estimated 2.3 billion people lacked even a basic sanitation service and 892 million people worldwide still practised open defecation (WHO/UNICEF, 2017). More recent data indicates that while progress has been made, unsafe water sources remain a primary cause of mortality in low-income countries, with diarrheal diseases accounting for a significant number of deaths, particularly among children under five (Wolf *et al.,* 2022).

Bacteriological quality is one of the important parameters of water potability. It is the measured by the presence of a pollution indicator of organisms, in particular, total germs and fecal coliforms (*Escharichia coli*). Total germs represent the desity of the bacterial population in drinking water. In determining water quality, the use of indicator bacteria such as faecal coliforms is commonly used. Coliforms and *Escherichia coli* are excellent significance for bacterial indices used in water quality evaluation (Torimiro *et al*., 2014). Physical chemical parameters such as dissolved oxygen, pH, temperature, conductivity, total alkalinity,

total hardness, total solids, transparency values, carbon dioxide, nitrite nitrogen, sulphates, carbonates and ammonia are some of the important variables for human health (Fafioye, 2011; Onianwah *et al*., 2018). There is need to constantly evaluate fresh water sources to know their pollution status with time. In view of this, fresh water sources in the North – Eastern Nigeria need to be subjected to bacteriological and physicochemical studies to ascertain their current pollution status because many human, natural and environmental unfriendly activities such as industrial effluent and domestic wastes impact water bodies. Recent studies in similar semi-arid regions of Nigeria continue to highlight the exacerbation of water quality issues due to anthropogenic pressures and climate variability (Ezekwe *et al.,* 2022).

Statement of the Problem

Freshwater resources in Gombe State, Nigeria are facing alarming levels of pollution, threatening human health, ecosystems and economic development. The region's water bodies are contaminated with harmful bacteria, viruses and physicochemical pollutants, due to inadequate wastewater management, Agricultural runoff, domestic waste disposal and climate change. This pollution poses significant risks to human health: Waterborne diseases examples cholera, typhoid, diarrhea; Environment: Harm to aquatic life, soil degradation and loss of biodiversity and Economy: Impacts on agriculture, fisheries and tourism.

Justification of the Study

Assessing bacteriological quality and physicochemical parameters of freshwater pollution in Gombe State, Nigeria is crucial due to limited existing data current information on freshwater pollution in the region is inadequate, making it challenging to develop effective mitigation strategies. Increasing population pressure; the region's growing population exacerbates pollution, increasing the risk of waterborne diseases. Vulnerable communities; rural and urban communities rely heavily on contaminated water sources, disproportionately affecting women, children and marginalized groups.

Economic implications; Freshwater pollution affects agriculture, fisheries and tourism, compromising economic development and livelihoods.

Climate change rising temperatures and changing precipitation patterns intensify pollution, necessitating adaptive management strategies.

Aim and Objectives

The aim of the study is to assess the bacteriological quality and physicochemical parameters of freshwater pollution and the associated risks in Gombe state, Nigeria.

Specific Objectives

The following objectives were set to be achieved:

i. To assess the bacteriological quality of freshwater sources in Gombe State, Nigeria, including the presence and levels of fecal coliforms and other pathogenic bacteria.

ii. To evaluate the physicochemical parameters of freshwater pollution in the region, such as pH, turbidity, dissolved oxygen and heavy metals levels.
iii. To identify the sources and potential causes of freshwater pollution in Gombe State, Nigeria, including anthropogenic activities, agricultural runoff and industrial effluents.
iv. To assess the associated risks of freshwater pollution to public health, agriculture, and the environment in the region.

Research Questions

This study seeks to understand:

1. What is the level of bacteriological contamination (total coliforms and Escherichia coli) in the major freshwater sources (Dams and Rivers) of Gombe State, Nigeria?
2. What are the physicochemical characteristcs (e.g. pH, turbidity, TDS, heavy metals, nitrate) of these freshwater sources?
3. To what extent do the measured bacteriological and physicochemical parameters in Gombe's freshwater sources comply with WHO and NAFDAC standards for water quality?
4. What are the primary sources and associated risk factors (public health, agricultural, environmental) contributing to the pollution of freshwater in Gombe State?

Hypotheses

The paper's methodology and findings suggest the following hypotheses were being tested (either explicity or implicity):

1. **Null Hypothesis (H_0)**: The bacteriological quality (total coliform and *E. coli* counts) of freshwater sources in Gombe State is not significantly different from WHO standard of 0 CFU/100ml.

   Alternative Hypothesis (H_1): The bacteriological quality of freshwater sources in Gombe State significantly exceeds the WHO standard of 0 CFU/100ml, indicating severe faecal contamination.
2. **Null Hypothesis (H_0):** The physicochemical parameters (e.g. turbidity, temperature, heavy metals, nitrate) of freshwater in Gombe State are within the acceptable limits set by WHO and NAFDAC

   Alternative Hypothesis (H_1): Key physicochemical parameters (specifically turbidity, temperature, chromium, and nitrate) in Gombe's freshwater significantly exceed the acceptable limits set byWHO and NAFDAC.
3. Null Hypothesis **(H_0):** There is no significant variation in the levels of contamination between the different sampled locations (Dams vs Rivers).

   Alternative Hypothesis (H_1): There is a significant variation in contamination levels between sampling locations, with sites near intense human activity and agricultural runoff (e.g. Balanga Dam, Dadinkowa Dam) showing higher pollution levels.

The results of the study strongly reject the null hypotheses (H_0) and support the alternative hypotheses (H_1), as all sampled locations showed significant contamination beyond guideline limits, wth notable variation among sites.

Study Area

The study was conducted in Gombe State, Nigeria, is bordered by Borno and Yobe States to the north and northeast, Taraba State to the south, Adamawa State to the southeast and Bauchi State to the west. (Kyari, 2020). Gombe is located between latitudes 9^0 30" and 12^0 30" North and longitudes 8^0 45" and 11^0 45" East. The State lies in the centre of the North – East geopolitical zone of Nigeria at latitude of 11.5132^0 North, longitude of 12.8753^0 East (NGSA., 2018). The State covers approximately 18,768 square kilometers, ranking 22^{nd} in terms of area among Nigeria's 36 states. Gombe has a tropical West Sudanian savanna ecoregion climate, characterized by two distinct seasons: dry (November to March) and rainy (April to October). The State population is estimated around 3,960,100 people as of 2022 (NMA., 2020, NBS., 2019, FAO., 2017 and ADB., 2019).

The state economy is primarily based on agriculture, with crops like sorghum, maize, groundnuts, millet, beans, rice and tomatoes being major produce. And there are availability of some mineral resources such as untapped crude oil in some parts of Borno, Yobe, Gombe and Bauchi states (Bello *et al*., 2019).

Sample Collection

The sample collection procedures were based on (APHA., 2005). The samples for bacteriological analysis and physicochemical parameters were collected on the same day from fresh surface waters to achieve consistency in sampling. Accordingly, samples were collected from seven (7) different locations of Gombe fresh surface water (about 30cm in depth). Temperature, dissolved oxygen, pH, TDS and conductivity were measured on – site at the time of sampling. Water samples for bacteriological quality analyses were collected using sterilzed 200 ml glass bottles, but 500 ml acid – washed polyethylene bottles were used to collect water samples for the analyses of the remaining chemical parameters. Before the collection of the samples, the containers were thoroughly rinse with the freshwater. The samples were transported to the laboratory using icebox, and analyses started within 2 hours of collection. The sampling was within two (2) months and the time was between 7am and 8am. Gombe town has various water supply points, including rural domestic water supply points. The specific locations of freshwater for this study were collected from Six (6) Local Government Areas of Gombe State, Nigeria; the sources included Four (4) Dams and Three (3) Rivers. The sampling was within two (2) months and the time was between 7am and 8am (Table 1)

Determination of Coliforms

The coliform count was calculated using the multiple tubes most probable number (MPN) method. In doing so, fifteen culture tubes were used per sample where five tubes containing sterile 10 ml double strength and ten tubes containing 10 ml single strength MacConkey broth

(HiMedia, India), and all tubes were fitted with inverted Durham tubes. Then, 10 ml of the water sample was aseptically dispense into each of the first five culture tubes containing the double strength MacConkey broth. One milliliter of the sample was inoculated into each of the five culture tubes containing sterile single strength MacConkey broth, while a 0.1 ml sample was inoculated into the remaining five tubes. The tubes were gently shaken to distribute the sample

1: Freshwater Location of the study areas, Date and Time of Collection

S/N	State	L.G.A.	Location	Name (Dam/River)	Date	Time
Gm001	Gombe	Akko	Maiganga	Maiganga Dam	6/10/2025	7:09AM
Gm002	Gombe	Kaltungo	Kalargu	Kalargu Dam	8/10/2025	8:32AM
Gm003	Gombe	Balanga	Putoki	River Kulani	13/10/2025	7:10AM
Gm004	Gombe	Balanga	Jamjara Village	Balanga Dam	16/10/2025	7:05AM
Gm005	Gombe	Y/Deba	Dadinkowa	Dadinkowa Dam	20/10/2025	8:00AM
Gm006	Gombe	Nafada	Ashaka Gari	River Gongola	23/10/2025	8:25AM
Gm007	Gombe	Dukku	Gombe Abba	River Gongola	29/10/2025	8:04AM

Uniformly throughout the medium and incubated at 37^0C for 24 hours of incubation, the cultures were observed for acid and gas production.

For the confirmatory test, a loop full of culture from test tubes that showed gas production were transferred to the brilliant green lactose bile (BGLB) broth tube and incubated for 24 to 48 hours at 35^0C. Tubes showing gas production inside Durham tubes, growth/turbidity/, and color change of purple MacConkey broth to yellow were considered as positive for total coliforms (TC). Finally, the results were reported as the most probable number (MPN) per 100 milliliters of water sample.

Determination of Physico-chemical Parameters

Physicochemical parameters of freshwater pollution in the region, such as pH, turbidity, dissolved oxygen and heavy metals levels, Nitrate (NO_3^-) and ammonia (NH_3^+) were determined following the procedure (APHA., 2005). Five days biological oxygen demand (BOD) was determined by using BOD OxiTop meter as described in Yuan *et al*. (2001).

Data Analysis

Statistical analyses was performed using SPSS software version (SPSS Inc, Chicago, USA). Coliform counts and measured values of physicochemical parameters were compared with the WHO or EPA guidelines for surface water quality. The values were also compared among sites for significant differences using parametric or nonparametric statistical tests. A significance level of $P \leq 0.05$ was applied for all the statistical tests.

RESULT

All sampled locations exceeded WHO standards (0 CFU/100ml for coliforms and *E. coli* (Table 2). The highest contamination was observed in Balanga Dam (3500 CFU/100ml coliforms, 2400 CFU/100ml *E. coli*), followed by Dadin-kowa Dam (3200 CFU/100ml coliforms, 1800 CFU/100ml *E. coli*), among the least were Ashaka Geri and Gombe Abba with (1200 CFU/100ml coliforms, 300 CFU/100ml *E. coli*) and (700 CFU/100ml coliforms, 400 CFU/100ml *E. coli*) respectively.

Table 3 describes the result of the chemical parameters of the water samples analyzed in the study. The highest pH range was recorded in Gombe Abba (7.96) while the least was recorded in Kalargu (7.06), as for the turbidity, the highest was recorded in Dadin-kowa (1098), while, Putoki (48.0) had the least. TDS revealed that Gombe Abba (561 mg/L) recorded the highest, Putoki (3 mg/L) stood as the least. Conductivity showed that Putoki (348 µS/cm) had the highest, while Dadin Kowa (82 µS/cm) represent the least, Dissolved oxygen revealed that Gombe Abba (7.90 mg/L) had the highest, while Jamjara Village (5.00 mg/L) had the least. As for chromium, Jamjara Village and Gombe Abba had the highest with 2.0 mg/L each, while Putoki had nothing recorded. Nitrate showed that Putoki (100 mg/L) had the highest, while Jamjara village (20 mg/L). The amount of Sulfate recorded showed that Dadin-kowa and Ashaka Geri had 180 mg/L each as the highest, while Jamjara village had 20 mg/L as the least. As for the ammonia content, Putoki, Jamjara Village and Gombe Abba had the highest with 0.2 mg/L each, while Maiganga, Kalargu and Ashaka Geri were Gelow Detection Limit (BDL). Biological Oxygen Demand revealed that Ashaka Geri had the highest with 3.10 mg/L, and Gombe Abba had the least with 1.60 mg/L (Table 3)

The sources and causes of freshwater pollution in Gombe State showed that it ranges from agricultural runoff due to excessive usage of fertilizers, pesticides and animal waste to animals wastes from livestock and grazing (Table 4)

The associated risk factors of freshwater pollution in Gombe State showed that three categories were identified, these were; Public health risks which include waterborne diseases and chemical poisoning. Agricultural risks covers soil degradation and livestock poisoning and Environmental risks had biodiversity loss and groundwater depletion as parts of its risks (Table 5)

Table 2: Coliform and *Escherichia coli* counts

S/N	Location	Name (Dam/River)	Coliform Count (CFU/100ml)	Escherichia coli (CFU/100ml)
Gm001	Maiganga	Maiganga Dam	2200	800
Gm002	Kalargu	Kalargu Dam	1300	700
Gm003	Putoki	River Kulani	2700	2000
Gm004	Jamjara Village	Balanga Dam	3500	2400
Gm005	Dadinkowa	Dadinkowa Dam	3200	1800
Gm006	Ashaka Gari	River Gongola	1200	300
Gm007	Gombe Abba	River Gongola	700	400
WHO Standard			0	0

Table 3: Physico–chemical parameters of collected water samples

Parameters	WHO	NAFDAC	Sampling Sites						
			MG	KG	PK	JV	DK	AG	GA
Ph	6.0 – 9.5	6.5 – 8.5	7.35	7.06	7.86	7.00	7..79	7.77	7.96
Temperature	$\leq 30^0$	$\leq 25^0$C	33	33	33	33	30	26	26
Turbidity	≤ 1 NTU	≤0.5 NTU	416	207	48.0	59.0	1098	836	442
TDS	≤2000 mg/L	≤500 mg/L	108	59.0	3.00	10.0	289	239	561
Conductivity	≤800 µS/cm	≤1000 µS/cm	161	121	348	157	82.0	131	94.0
Dissolved Oxygen	≤8 mg/L	≤8 mg/L	6.00	5.80	6.00	5.00	5.20	5.50	7.90
Chromium	≤0.05 mg/L	≤0.05 mg/L	0.1	0.1	0	0.2	0.1	0.2	0.1
Nitrate	≤100 mg/L	≤ 45 mg/L	90	50	100	30	45	44	33
Sulfate	≤500 mg/L	≤200 mg/L	80.0	50.0	43.0	20.0	180	180	96.0
Ammonia	≤1.5 mg/L	≤1.5 mg/L	BDL	BDL	0.2	0.2	0.1	BDL	0.2
BOD	≤5 mg/L	≤5 mg/L	2.20	2.40	1.70	1.90	2.50	3.10	1.60

Key: MG = Maiganga , KG = Kalargu, PK = Putoki, JV = Jamjara Village, DK = Dadinkowa, AG = Ashaka Gari, GA = Gombe Abba, BDL = Below Detection Level, BOD = Biological Oxygen Demand

Table 4: Sources and potential causes of freshwater pollution in Gombe State, Nigeria

Sources	Potential Causes of freshwater pollution in Gombe State
Agricultural runoff	Excessive use of fertilizers, pesticides, and animal waste from farming activities leading to nutrient pollution in rivers like Gongola.
Industrial and Mining Activities	Small – scale industries, quarrying and mining (e.g. limestone mining) release heavy metals and sediments into water bodies.
Domestic and Urban Wastewater	Poor sewage system, open defecation and untreated household waste entering streams and rivers.
Solid Wastes and Plastics	Improper disposal of plastics and household waste clogging waterways and leaching toxins.
Deforestation and Erosion	Land clearing for Agriculture leading to increased sedimention in rivers like Dadin – Kowa Dam.
Livestock and Grazing	Animal waste from open grazing contaminate freshwater sources with pathogens and nutrients.

Table 5: Risk Factors of freshwater pollution in Gombe State, Nigeria.

Category	Associated Risks
Public Health Risks	
Waterborne Diseases	Contamination by pathogens (e.g. cholera, typhoid, dysentery) due to poor sewage disposal and open defecation.
Chemical Poisoning	Heavy metals (lead, mercury) from mining and industrial waste cause kidney damage, cancer and neurological disorder.
Nitrate Pollution	High nitrate levels from fertilizers linked blue baby syndrome (methemoglobinemia) in infants
Agricultural Risks	
Soil Degradation	Salinization and toxic chemical builtup reduce soil fertility, lowering crop yields.
Crop Contamination	Heavy metals (e.g. cadmium, arsenic) absorbed by crops, make them unsafe for human consumption.
Livestock Poisoning	Animals drinking polluted water suffer from diseases reducing milk/meat quality and productivity.
Environmental Risks	
Biodiversity Loss	Fish kills and aquatic ecosystem collapse due to eutrophication and toxic chemicals.
Groundwater Depletion	Pollution reduces safe drinking water availability, increasing reliance on unsafe sources.
Sedimentation and Flooding	Deforestation and erosion increase siltation in rivers (e.g. river Gongola), worsening floods.

DISCUSSION

The study's findings highlight severe contamination of freshwater sources in Gombe State, Nigeria, with significant implications for public health, agriculture and environment. The results aligned with global concern about water pollution in developing regions, particularly where sanitation infrastructure is lacking (UNICEF /WHO, 2017). All sampled locations exceeded WHO standards (0 CFU/100ml for coliforms and *E. coli*. The high contamination observed in Balanga Dam could be likely due to the proximity to human settlements and agricultural runoff. These results corroborate studies linking fecal contamination to open defecation and poor waste management (Chigor *et al*., 2012; Idu, 2015). Similar patterns of high fecal indicator bacteria in surface waters, strongly associated with nearby human and animal activities, have been consistently reported across Nigeria in recent years (Osuagwu *et al.,* 2023). The presence of *E. coli* indicates fecal contamination, posing risks of waterborne diseases like cholera and typhoid as stated by Cabral, (2010); WHO, (2019).

The Environmental Protection Agency (EPA) considers Total Coliform as an indicator of other pathogens in drinking water, and it is used to determine satisfactory water treatment and integrity in the distribution system (USEPA, 2013). Therefore, there should be no such organisms in any drinking water source as the maximum limit of contaminant of pathogenic

bacteria such as Total coliform and *Escherichia coli* is 0 for drinking water (Rohmah *et al.,* 2018). The presence of extremely large amount of coliforms in this study clearly violated the guidelines for drinking water quality. pH levels in the present study were within WHO/NAFDAC guidelines (6.5 – 8.5), but Temperature exceeds the recommended limits of ($\leq 30^0$C), thereby potentially accelerating microbial growth as opined by Yuan *et al.* (2001). Turbidity levels (48 – 1098 NTU) far exceeded WHO limits (≤ 1 NTU), with Dadin-kowa Dam showing the highest turbidity (1098 NTU), this could be due to erosion and sedimentation. High TDS recorded at Gombe Abba suggests mineral runoff or industrial discharge (APHA, 2005).

Heavy metals such as chromium levels in the present study surpassed WHO limits (≤0.05 mg/L), this could be linked to mining activities observed. The persistence of heavy metals like chromium in African water bodies, often from artisanal and small-scale mining, continues to be a major environmental and public health concern, as highlighted in contemporary regional assessments (Edori & Iyama, 2023). Nitrate levels in the present study approached the thresholds, risking methemoglobinemia in infants (WHO, 2011). Fertilizers and mining introduced nitrates and heavy metals in the present study, this is consistent with global patterns of non–point source pollution (Kistemann *et al.,* 2002). Elevated Biological Oxygen Demand (BOD) and turbidity recorded in the present study has been known to threaten aquatic life, excerbating biodiversity loss (Khukinskii, 2003). The high coliform and *Escherichia coli* counts in the present study is an indication of faecal contamination of water, which has been associated with the development of several water borne gastrointestinal illnesses (Kaper *et al.,* 2004; Maier, 2009). This portends serious health risks for infants, young children and people with compromised immune systems (USEPA, 2013; Rohmah *et al.,* 2018). The interconnected risks of microbiological and chemical contamination in water sources, as found in this study, underscore the complex challenge of achieving water security, a issue increasingly framed within the context of achieving Sustainable Development Goal 6 (UN-Water, 2021).

CONCLUSION

The study on freshwater pollution in Gombe State, Nigeria, reveals alarming contamination levels across major water sources, including dams (e.g., Balanga, Dadin-kowa) and rivers (e.g., Gongola, Kulani). These results align with global challenges in developing regions, where inadequate infrastructure and lax regulations exacerbate water pollution. Gombe State's freshwater crisis demands urgent, multi-sectoral action. By integrating stricter regulations, community participation, and sustainable practices, the state can safeguard water resources for future generations.

RECOMMENDATIONS

To mitigate freshwater pollution in Gombe State, the following measures are proposed:

i. **Policy and Regulatory Enforcement**

Strengthen Monitoring: Enforce compliance with WHO/NAFDAC standards through regular water quality audits by agencies like NESREA.

Industrial Regulations: Mandate pretreatment of effluents from mining and textile industries.

ii. **Improved Sanitation and Waste Management**

Sanitation Infrastructure: Expand sewage systems and promote community-led total sanitation (CLTS) to reduce open defecation.

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