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PHYSICOCHEMICAL AND MICROBIOLOGICAL QUALITY OF THE IKOT OKORO RIVER DRAINAGE BASIN, ORUK ANAM, AKWA IBOM STATE, NIGERIA: COMPLIANCE WITH WHO AND NIGERIAN DRINKING-WATER STANDARDS

Kenneth Isaac UKOETE
Abia State University, Uturu
ukoetek@gmail.com

ABSTRACT

Rural communities in the humid tropics often depend on untreated surface water, yet baseline data on its quality are scarce. This study assessed the physicochemical and microbiological quality of the Ikot Okoro River drainage basin in Oruk Anam Local Government Area, Akwa Ibom State, southern Nigeria, and compared the results with the WHO Guidelines for Drinking-water Quality (2017) and the Nigerian Standard for Drinking Water Quality (NIS 554:2007). Water was sampled at five community drinking-water points (WS1–WS5) in the wet season (September 2022) and the dry season (February 2023), giving ten samples. Twenty-one physical and chemical variables and two bacteriological indicators (total coliform and *Escherichia coli*) were determined using standard procedures. The water was strongly acidic (pH 4.01–4.75; overall mean 4.36), dilute (electrical conductivity 5.6–13.4 µS/cm), and in the dry season, severely oxygen-depleted (dissolved oxygen 0.6–0.8 mg/L). Nickel exceeded both the WHO guideline (0.07 mg/L) and the Nigerian limit (0.02 mg/L) in seven of ten samples (overall mean 0.69 mg/L). Every sample contained coliform bacteria (15–67 cfu/100 mL) and nine of ten contained *E. coli* (up to 6 cfu/100 mL), against a guideline value of zero. Other measured variables, including turbidity, chloride, sulphate, nitrate, nitrite, iron, copper and zinc, were within the respective limits. The basin water is therefore unsafe for drinking without treatment. Household-level treatment, protection of drinking-water points and confirmation of the nickel result by atomic absorption spectrometry are recommended as immediate priorities.

Keywords: *Drinking-Water Quality; Faecal Contamination; Nickel; Acidic Water; Rural Water Supply*

1. Introduction

Access to safe drinking water is a precondition for public health and a core target of Sustainable Development Goal 6 (United Nations, 2015). Globally, inadequate water, sanitation and hygiene remain major causes of diarrhoeal disease, and the burden falls most heavily on low- and middle-income countries (Prüss-Ustün *et al*., 2019). Joint monitoring data show that hundreds of millions of people still collect drinking water directly from rivers, streams and other untreated surface sources (WHO/UNICEF Joint Monitoring Programme [JMP], 2023). Water quality is not an absolute property. It describes the suitability of water for a particular use, and the same water may be acceptable for irrigation or bathing but unsafe for drinking (Chapman, 1996). Drinking-water assessment therefore rests on comparing measured physical, chemical and microbiological variables with health-based and acceptability guidelines, notably those of the World Health Organization (WHO, 2017) and, in Nigeria, the Standards Organisation of Nigeria (SON, 2007). Surface-water quality is also shaped by the catchment: land use, vegetation cover and human settlement all influence what a stream carries (Allan *et al.,* 1997; Allan, 2004; Osborne & Wiley, 1988; Lenat & Crawford, 1994; Pekárová & Pekár, 1996; Silva & Williams, 2001).

In Oruk Anam Local Government Area (LGA) of Akwa Ibom State, the Ikot Okoro River and its associated streams are the principal source of water for domestic and commercial use in several communities. Local livelihoods are dominated by subsistence farming, fishing and trading. Nearby Akwa Ibom rivers have been reported to be slightly acidic with low dissolved oxygen (Denise & John, 2014), and studies elsewhere in Nigeria report variable compliance of rivers and streams with drinking-water limits (Anyanwu *et al*., 2022; Uzochukwu & Ugochukwu, 2019). However, no published baseline exists, to our knowledge, for the Ikot Okoro drainage basin. Without such data, communities and the authorities cannot judge whether the water is safe or what treatment it requires. This paper addresses that gap. Its objectives were (i) to assess the physicochemical quality

of the Ikot Okoro River drainage basin and (ii) to assess its microbiological quality, in both cases against WHO and Nigerian drinking-water standards.

2. Materials and methods

2.1 Study area

Oruk Anam LGA lies in the South-South geopolitical zone of Nigeria, in Akwa Ibom State, and is bordered by the Ikot Abasi, Mkpat Enin and Ukanafun LGAs (Figure 1). The 2006 census put the LGA population at 171,837, predominantly of Annang ethnic affiliation. The area has a humid tropical climate with a pronounced wet season (peak monthly rainfall of about 13–14 inches in August–September) and a dry season with under 1 inch of rain in December–January; mean monthly temperature is about 24–27 °C. The vegetation is characteristic of the oil-palm belt of southern Nigeria, and agriculture, fishing and trading are the main economic activities. The study covered the Ikot Okoro River and associated streams serving the communities of Ikot Okoro, Ibianga, Ikot Obio Nso, Inen Nsai and Ikpe Akpa Ewe.

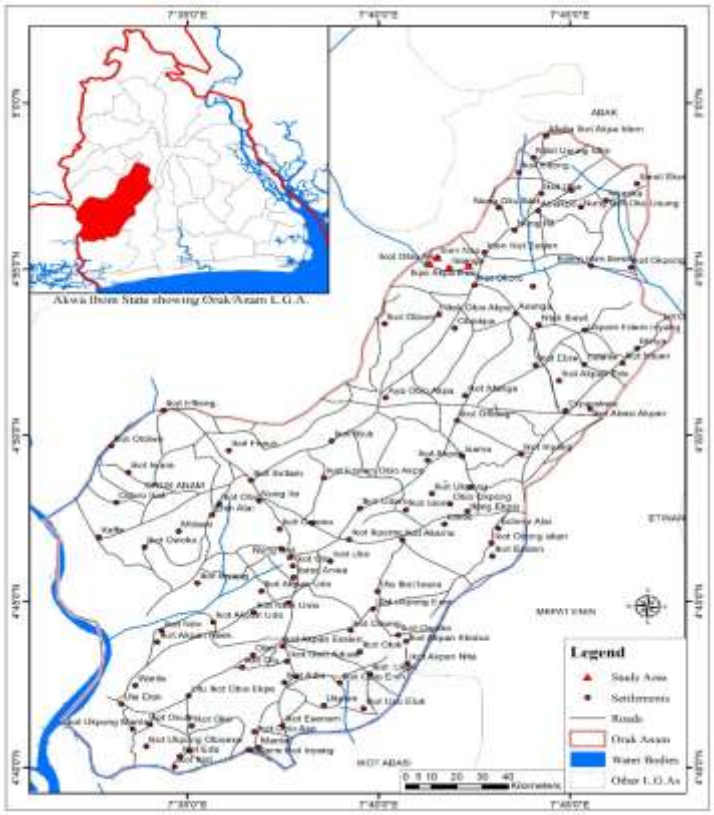

Figure 1:Map of Oruk Anam Local Government Area showing the Study Area.
Source: Cartography and Map library Studio, Department of Geography UNIUYO (2023)

2.2 Sampling design

Five sampling points (WS1–WS5) were selected at community drinking-water points on the river and its streams and were geo-referenced with a hand-held GPS. One sample was collected at each point in the wet season (September 2022) and one in the dry season (February 2023), giving ten samples. Samples were collected in pre-sterilised 2-litre plastic containers rinsed with water to be sampled, labelled, kept in an ice-cooled box and transported to the laboratory, where they were refrigerated and analysed within recommended holding times (APHA *et al.,* 2017). Temperature and pH were measured in situ or immediately on collection. Laboratory analysis was carried out at the environmental laboratory, Akwa Ibom State Ministry of Science and Technology, Uyo, Akwa Ibom State.

2.3 Laboratory analysis

Twenty-one variables were measured: temperature, electrical conductivity (EC), turbidity and salinity (physical); and pH, total dissolved solids (TDS), total hardness, calcium hardness, alkalinity, dissolved oxygen (DO), biochemical oxygen demand (BOD), iron, sulphate, chloride, copper, zinc, nickel, nitrate, nitrite, ammonia and phosphate (chemical). Temperature was read with a mercury-in-glass thermometer between 06:00 and 09:00. pH was measured with a calibrated portable meter (SUNTEX TS-2) standardised against phosphate buffer, and EC with a conductivity meter standardised with 0.01 M KCl. Turbidity was read on a turbidity meter. Total and calcium hardness were determined by EDTA titration (Eriochrome Black T), alkalinity by titration with 0.01 N H_2SO_4, and DO by the Winkler method; BOD was calculated as the difference between initial DO and DO after five days of incubation at 20 °C. Nitrate, nitrite, sulphate, phosphate, ammonia and chloride were read on a spectrophotometer and nickel, iron, zinc and copper by portable photometric methods against prepared stock standards, all reported in mg/L. Total coliform and *E. coli* were enumerated by the standard plate-count (membrane-filtration) technique on 100 mL of sample, with media autoclaved at 121 °C, plates incubated for 24-48 h, and colonies counted and expressed as colony-forming units per 100 mL

(cfu/100 mL).

2.4 Assessment against standards

Results were compared with the WHO (2017) guideline values and the Nigerian Standard for Drinking Water Quality (SON, 2007). Where neither document sets a limit (for example, alkalinity, DO, BOD and phosphate), the result is described but not classed as compliant or non-compliant. Descriptive statistics (mean, minimum, maximum) were computed for each season and for the two seasons combined.

3. Results and discussion

3.1 Physical characteristics

Table 1 summarises the physical variables. Water temperature averaged 15.3 °C in the wet season and 29.3 °C in the dry season. Electrical conductivity was very low (wet mean 6.9 µS/cm; dry mean 10.4 µS/cm), far below the Nigerian limit of 1,000 µS/cm, and TDS was correspondingly low (3.1 and 3.9 mg/L). Turbidity ranged from 0.59 to 3.82 NTU and was within the 5 NTU limit at all points. No salinity was detected. The very low conductivity shows that the water is dilute and not influenced by saline intrusion or high dissolved-solid loads.

The wet-season temperature of 15.3 °C is unusually low for a lowland tropical stream, where surface water temperatures of 24–28 °C are typical. It may reflect early-morning measurement conditions or a recording issue, and it should be read with caution; it does not bear on any drinking-water standard.

Table 1. Physical variables (mean, with range in parentheses; n = 5 points per season).

Variable	Unit	Wet season	Dry season	Limit (SON, 2007)
Temperature	°C	15.3 (13.9–16.9)	29.3 (29.1–29.4)	Ambient
Electrical conductivity	µS/cm	6.92 (5.57–9.31)	10.42 (8.90–13.44)	1,000
Turbidity	NTU	1.44 (1.03–2.59)	1.75 (0.59–3.82)	5
Salinity	mg/L	0.00	0.00	–
TDS	mg/L	3.1 (2.7–3.5)	3.9 (3.3–5.0)	500

3.2 pH, oxygen status and general chemistry

pH: The water was strongly acidic at every point (4.01–4.75; Table 2), well below the 6.5–8.5 range recommended by WHO (2017) and SON (2007). Wet-season pH (mean 4.54) was higher than dry-season pH (mean 4.18). The dissertation from which this study derives attributed the acidity to pollution from agricultural runoff and wastewater. That explanation is plausible, but acidity of this degree can also arise naturally in forested and palm-belt catchments on sandy coastal-plain soils, where organic (humic) acids and low buffering capacity depress pH (Chapman, 1996). Alkalinity was low (wet mean 19.0 mg/L; dry mean 7.2 mg/L), which indicates little buffering capacity and means the water is easily acidified. Neither explanation was tested here; separating natural from anthropogenic acidity would need measurements of organic carbon, soil and rainfall chemistry. Low pH is not itself a direct health risk at this level, but it increases the solubility and mobility of metals, can corrode pipes and storage containers, and is detrimental to aquatic life.

Dissolved oxygen and organic load: DO averaged 4.0 mg/L in the wet season but only 0.7 mg/L in the dry season (range 0.6–0.8 mg/L), a level close to hypoxia that cannot support most fish and aquatic invertebrates (Chapman, 1996). BOD was low in both seasons (2.8 and 0.09 mg/L). Because BOD falls sharply as DO falls, and the two were strongly correlated across the ten samples ($r = 0.88$), the very low dry-season BOD should be interpreted cautiously: when initial oxygen is nearly exhausted, a five-day BOD test cannot register much additional demand. The dry-season oxygen depletion likely reflects low flow, high temperature, and the decomposition of organic matter in near-stagnant water, but this too remains an inference.

Hardness. Total hardness averaged 45.2 mg/L (wet) and 52.8 mg/L (dry), i.e. soft water and well below the Nigerian limit of 150 mg/L.

Table 2. Chemical variables (recalculated means from site data, with range in parentheses; n = 5 per season).

Variable	Unit	Wet season	Dry season	Limit(SON, 2007)/WHO (2017)
pH	–	4.54 (4.35–4.75)	4.18 (4.01–4.40)	6.5–8.5
Alkalinity	mg/L	18.96 (14.4–22.8)	7.20 (4.8–9.6)	–
Total hardness	mg/L	45.2 (36–52)	52.8 (20–90)	150 (SON)
Calcium hardness	mg/L	46.4 (28–66)	43.6 (14–60)	–
Dissolved oxygen	mg/L	4.04 (1.5–5.7)	0.68 (0.6–0.8)	–
BOD	mg/L	2.76 (2.5–3.0)	0.088 (0.08–0.09)	–
Chloride	mg/L	0.28 (0.01–0.60)	0.14 (0.01–0.60)	250
Sulphate	mg/L	0.002 (0.001–0.007)	0.003 (0.001–0.010)	100 (SON)
Nitrate	mg/L	0.040 (0.01–0.08)	0.016 (0.01–0.04)	50
Nitrite	mg/L	0.0056 (0.001–0.010)	0.0052 (0.001–0.010)	0.2 (SON)
Ammonia	mg/L	0.000	0.002 (0–0.01)	–
Phosphate	mg/L	41.0 (0.01–106)*	0.088 (0.08–0.09)	No guideline

*See section 3.3.

3.3 Metals and nutrients

Nickel. Nickel is the most significant chemical finding. Concentrations ranged from 0.01 to 1.48 mg/L, with a wet-season mean of 0.78 mg/L and a dry-season mean of 0.60 mg/L (overall mean 0.69 mg/L). Seven of ten samples (four of five in the wet season, three of five in the dry season) exceeded both the WHO guideline of 0.07 mg/L and the Nigerian limit of 0.02 mg/L, some by more than an order of magnitude. Elevated nickel in drinking water is associated with allergic skin sensitisation in nickel-sensitive individuals and, at sustained high exposure, with other toxic effects (WHO, 2017). The two highest values (1.48 and 1.31 mg/L in the wet season; 1.38 and 1.01 mg/L in the dry season) occurred at the same two points (WS2, WS3) in both seasons, indicating a persistent local source rather than a seasonal pulse. The dissertation compared nickel with a WHO value of 5.0 mg/L; the current WHO guideline is 0.07 mg/L, so the exceedance is larger than previously reported. Possible sources (for example agrochemicals, corroding metal containers, waste burning and dumping)

were not investigated. Because the measurements were made with a portable photometric device, confirmation by atomic absorption or ICP-based methods is essential before this finding is relied on for management.

Other metals. Iron (recalculated means 0.0008 mg/L wet; 0.068 mg/L dry), copper (0.10 and 0.11 mg/L) and zinc (0.012 and 0.042 mg/L) were all within the respective limits at every point (maximum iron 0.27 mg/L against 0.3 mg/L; copper 0.36 mg/L against 1.0 mg/L; zinc 0.18 mg/L against 3.0 mg/L).

Nitrogen and phosphorus. Nitrate, nitrite and ammonia were present at trace levels, indicating no appreciable nitrogenous (sewage or fertiliser) enrichment at the time of sampling. Phosphate was reported as 0.0-0.01 mg/L at two wet-season points but 55, 44 and 106 mg/L at the other three, against 0.08-0.09 mg/L at all dry-season points. Concentrations of tens of mg/L in a diluted, low-conductivity river are chemically implausible and may reflect a unit or transcription error; neither WHO nor SON sets a health-based phosphate guideline, so no compliance judgement is made. Phosphate should be re-measured, because genuinely elevated phosphorus would indicate nutrient enrichment from detergents, waste or fertiliser.

3.4 Microbiological quality

All ten samples were contaminated (Table 3). Total coliform counts ranged from 30 to 67 cfu/100 mL in the wet season (mean 49.6) and from 15 to 27 cfu/100 mL in the dry season (mean 20.0). *E. coli*, the preferred indicator of recent faecal contamination (Ashbolt *et al.,* 2001; Odonkor & Ampofo, 2013), was present in nine of ten samples (0-6 cfu/100 mL), whereas WHO (2017) and SON (2007) require none in any 100 mL sample intended for drinking. The highest counts were found at WS2 and WS3 in the wet season (coliform 55 and 67; *E. coli* 5 and 6 cfu/100 mL), the same points with the highest nickel.

Table 3. Bacteriological quality (cfu/100 mL; WHO and SON guideline = 0).

Point	Total coliform, wet	Total coliform, dry	*E. coli*, wet	*E. coli*, dry
WS1	30	19	1	1
WS2	55	15	5	2
WS3	67	19	6	2
WS4	51	20	1	1
WS5	45	27	0	2
Mean	49.6	20.0	2.6	1.6

The pattern is consistent with a basin in which the drinking-water points receive human and animal waste, and with a settlement context in which pit latrines predominate and a substantial share of households dispose of waste in or near the river (examined in the companion paper on sanitation and sustainability). Faecal contamination of this kind is the principal pathway for cholera, typhoid and other diarrhoeal infections (Prüss-Ustün *et al.,* 2019). The *E. coli* counts are low in absolute terms, but the guideline for drinking water is zero, and low counts in a single sample cannot exclude a higher risk at other times, particularly after rainfall.

3.5 Compliance with standards

Table 4 compares the overall means with the guideline values and records how many of the ten samples breached each limit. Four of the variables with a limit failed: pH (10/10 samples), nickel (7/10), total coliform (10/10) and *E. coli* (9/10). All others with a limit complied at every point.

Table 4. Compliance of the ten samples with drinking-water standards.

Variable	Overall mean	WHO (2017)	SON NIS 554 (2007)	Samples breaching limit
pH	4.36	6.5–8.5 (operational)	6.5–8.5	10/10
Turbidity (NTU)	1.60	≤5 (acceptability)	5	0/10
EC (µS/cm)	8.67	–	1,000	0/10
TDS (mg/L)	3.49	<600 (palatability)	500	0/10
Chloride (mg/L)	0.21	250	250	0/10
Nitrate (mg/L)	0.028	50	50	0/10
Nitrite (mg/L)	0.0054	3 (acute)	0.2	0/10
Iron (mg/L)	0.035	–	0.3	0/10

Variable	Overall mean	WHO (2017)	SON NIS 554 (2007)	Samples breaching limit
Copper (mg/L)	0.108	2	1.0	0/10
Zinc (mg/L)	0.027	–	3.0	0/10
Nickel (mg/L)	0.69	0.07	0.02	7/10
Total coliform (cfu/100 mL)	34.8	0	0	10/10
E. coli (cfu/100 mL)	2.1	0	0	9/10

3.6 Implications for public health and management

Taken together, the results show that water from the Ikot Okoro drainage basin does not meet drinking-water standards and cannot be regarded as safe without treatment. The faecal indicators are the most pressing concern because they indicate a direct, immediate infection risk; the nickel result is also serious but requires confirmation. The strongly acidic pH and low alkalinity add a further practical issue: the water is aggressive toward metal containers and may mobilise metals.

Practical measures follow from this. (i) Households should treat water before drinking, using boiling, chlorination or a household filter, and should store it in covered, clean containers. (ii) Drinking-water points should be protected from contamination by fencing, drainage control and separation from bathing, washing and waste disposal. (iii) Nickel should be re-analysed by atomic absorption spectrometry, with the source investigated. (iv) The authorities should develop an improved water supply, such as boreholes or a small treated scheme, since almost all residents depend on the river (see the companion paper). (v) A routine monitoring programme at WS2 and WS3 in particular should be established.

4. Limitations

The study is a baseline with one sample per point per season, so within-season variation and short-term events (such as storm flow) were not captured, and the data support description rather than statistical inference about individual parameters. Metals and nutrients were measured by portable photometric and spectrophotometric methods rather than atomic absorption or ion chromatography. Several values should be re-verified against the laboratory

records before the data are used operationally: the wet-season temperature (15.3 °C); the phosphate values of 41–106 mg/L at three wet-season points; calcium hardness that exceeds total hardness at some points; and hardness values that seem high relative to the very low conductivity. Sources of pollution were inferred, not measured. Finally, health effects were not assessed; the findings indicate risk, not disease.

5. Conclusions

The Ikot Okoro River drainage basin is strongly acidic, dilute, and, in the dry season, severely oxygen-depleted, and its water is faecally contaminated at all five community drinking-water points. Nickel exceeded WHO and Nigerian limits in seven of ten samples. By contrast, turbidity, salinity, major ions, nitrogen species, iron, copper and zinc were within limits. The water is unfit for drinking without treatment. A confirmatory re-analysis of nickel and phosphate, a sanitary survey of the drinking-water points and a longer monitoring series should follow.

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