



Water Quality Assessment of the Kwa River, Calabar, Cross River State, Nigeria: Implications for Naval Operations, Amphibious Training, and Civil Engineering Construction

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ABSTRACT

This study presents a water quality assessment of the Kwa River in Calabar, Cross River State, Nigeria, focused on a sampling location near the Nigerian Naval Base and Amphibious Training School. The river serves two functions of direct engineering interest: military training, including amphibious exercises and personnel water-survival training, and civil engineering construction water supply for concrete production, soil compaction, equipment cooling, and dust suppression at infrastructure sites across Calabar municipality. A composite water sample was analysed for physical, chemical, and microbial parameters and compared against Nigerian Industrial Standard (NIS) limits for potable water and, separately, against widely cited construction-water benchmarks. The results show an acidic pH of 5.00, turbidity of 29.40 NTU (488% above the 5 NTU screening limit), nitrite at 0.21 mg/L, total coliform at 18 CFU/100 mL, and dissolved oxygen of 2.82 mg/L, all outside their respective NIS limits. A companion hydrographic survey established six spatial reference points (P1-P6) around the sampling location, providing elevation and coordinate control that helps explain probable pollutant-transport pathways and lays the groundwork for a spatially resolved monitoring programme. Screening-level indices computed from the chemistry - an Aggressiveness Index of 7.4 (classified as highly aggressive water), a turbidity-based pollution index of 488%, and a sulfate-acidity ratio of 8.73 - indicate that the water is chemically unsuited to direct use as concrete mixing or curing water without treatment, though this study stops short of the mortar and concrete performance testing that would be required to confirm the magnitude of any resulting deterioration. The findings point to compound implications for military operations, construction durability, public health, and aquatic ecosystem integrity, and they support a recommendation for water treatment, replicate and seasonal monitoring, and confirmatory concrete-performance testing before the river is relied upon as a construction water source.

Keywords: Kwa River, Calabar, water quality, naval base, amphibious training, civil engineering construction, concrete mixing water, aggressiveness index, river pollution, Cross River State, Nigeria

INTRODUCTION

The Great Kwa River is a significant water body in Calabar, Cross River State, southeastern Nigeria, forming an important component of the Cross River estuarine system and supporting aquatic ecosystems and human activities within the region (Edet et al., 2013; Emeka et al., 2026). The river and its associated creeks have been investigated for domestic, irrigation, fisheries, and ecological purposes, underlining its importance to local environmental sustainability and socioeconomic activity (Edet et al., 2013; Ephraim & Ajayi, 2015). Increasing urbanisation, municipal waste discharge, and other anthropogenic pressures around the river have, however, raised concerns about a decline in water quality and the associated ecological and human-health risks (Ekpo et al., 2021; Ekpo et al., 2024; Odey et al., 2024). Maintaining the quality of the Great Kwa River therefore matters for protecting aquatic ecosystems, supporting sustainable resource use, and promoting the environmental sustainability of Calabar and the wider Cross River region.

Beyond its ecological role, the river is an active military training and maritime-security environment. The Nigerian Army's Amphibious Training School (ATS), Calabar, uses the surrounding riverine, creek, and swamp environments to train personnel in amphibious and riverine operations, including navigation in difficult waterways (Cross River State Government, 2026; Nigerian Army, 2022). The same waterways support the Nigerian Navy's Eastern Naval Command and NNS Victory in maritime-security patrols along the shoreline of Cross River State (Blueprint Newspapers Limited, 2016). The river is thus an operational training environment in its own right, and the fitness of its water for the personnel and equipment that depend on it is a legitimate engineering and safety question, not only an ecological one.

Previous studies of the Great Kwa River system have reported comparatively low total dissolved solids, electrical conductivity, and salinity at some sampling locations, while noting that water quality varies spatially and seasonally (Ephraim & Ajayi, 2015). This variability means that the river's suitability for construction applications cannot be assumed from its natural appearance or ready availability; it must instead be established through direct physicochemical and microbiological assessment, particularly because surface-water quality in the wider Calabar river system is known to be affected by municipal, industrial, and other anthropogenic discharges (Stanley et al., 2017; Emeka et al., 2026).

Water quality matters for construction because it governs concrete strength development, durability, and reinforcement corrosion, and therefore the service life of any structure built with it. Harmful substances such as chlorides, sulfates, alkalis, and dissolved solids can measurably degrade concrete performance (ASTM International, 2022; ACI Committee 318, 2019). In the Nigerian context, poor-quality construction materials and weak quality control are already implicated in premature deterioration and structural failure (NBRRI, 2026), which raises the stakes of using an unassessed water source for mixing, curing, or compaction on infrastructure projects around the Naval Base and the wider Calabar area.

This study evaluates the suitability of Kwa River water for military and construction applications by assessing its physicochemical and microbiological characteristics against the Nigerian Industrial Standard (NIS) for drinking water, and, separately, against internationally recognised construction-water benchmarks (BS EN 1008 and ASTM C1602), the reasoning for which is set out explicitly in Section 2.6. A companion hydrographic survey establishes the spatial and elevation framework needed to interpret probable pollution pathways around the sampling location. The study also applies a set of screening-level engineering indices to gauge the aggressiveness of the water toward concrete and reinforcement, while being explicit about what a single reconnaissance-level sampling campaign can and cannot demonstrate. On that basis, the paper offers evidence-based recommendations on water treatment, monitoring design, and the further testing needed before any construction use of this water is finalised.

MATERIALS AND METHODS

Study Area

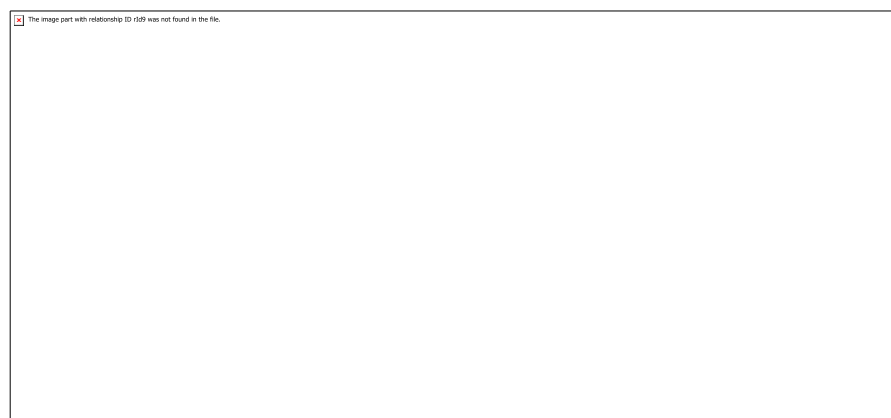


Figure 1. Map of the study area showing the Kwa River sampling location within Calabar, Cross River State.



Calabar, the capital of Cross River State, has a population of roughly 450,000 and lies between the Calabar River and the Great Kwa River. The city is undergoing rapid infrastructure development, including port modernisation, road expansion, residential estates, military facilities, and the proposed Bakassi Deep Sea Port. The stretch of the Kwa River around the Naval Base and Amphibious Training School is a tidal freshwater system characterised by sandy sediments and organic-matter accumulation. Its connection to the Cross River estuary produces tidal fluctuations that measurably affect water chemistry and sediment dynamics at the sampling location, a point returned to in Section 3.1 when interpreting the hydrographic survey.

Sampling Design and Procedure

A single composite sample of approximately 2,000 mL of brownish-coloured river water was collected from the Kwa River at the primary sampling/construction-intake point near the Nigerian Naval Base, Calabar (Base/TBM1 station; Northing 552,980.132 m, Easting 423,961.638 m; see Table 3), on 25 September 2024 at 10:00 h local time, during the tail end of the rainy season in Cross River State. Collection was from mid-channel at 0.5 m depth using a weighted Van Dorn sampler, a depth chosen to minimise interference from floating debris, surface films, and disturbed bottom sediment while remaining representative of the water column an intake pump would draw from.

This was a single-visit, single-point reconnaissance sampling campaign rather than a replicate or seasonal one: one composite sample was collected, and no repeat samples were drawn at the same station on other dates or tidal states. This scope is stated plainly here, and returned to in Section 3.7, because it constrains what can honestly be concluded about spatial and temporal variability at the site and what statistical treatment of the results is possible.

Pre-sampling Protocol

Sterile polyethylene bottles were washed and rinsed with distilled water, then triple-rinsed with river water at the sampling site immediately before collection. Each sample container was labelled with a unique identification code, the collection date and time, GPS coordinates, and the sampling location, to preserve traceability from field to laboratory.

Preservation and Transport

Samples were placed in an insulated cool box with ice packs immediately after collection and transported to FRIMO Analytical Consults, Calabar, for analysis. Table 1 summarises the preservation method applied to each parameter group.

Table 1: Preservation Method

Parameter Type	Preservation Method
Physicochemical	Refrigeration at 4 °C during transport
Microbiological	Kept on ice; intended analysis within 24 hours of collection

The certificate of analysis issued by the laboratory (Batch No. 05/10/24WPLRW) records the date of collection as 25 September 2024 and the date of analysis as 3 October 2024, an interval of roughly eight days. This exceeds the 24-hour holding time normally recommended for microbiological analysis under Standard Methods (APHA, AWWA, & WEF, 2023), and is acknowledged here as a limitation of the dataset: the reported total coliform count of 18 CFU/100 mL should be read as an indicator of contamination consistent with a polluted river rather than as a precise, holding-time-compliant enumeration. Physicochemical results, which tolerate longer, refrigerated holding, are less affected by this gap. This limitation, and the corrective step recommended for future sampling rounds, is discussed further in Sections 3.7 and 4.2.

Hydrographic and Topographic Survey

A hydrographic survey using a Total Station, a levelling instrument and staff, and a fixed benchmark control was carried out to establish the coordinates and reduced levels of the sampling location and six surrounding reference stations (P1-P6). The purpose of this survey is distinct from, and complementary to, the water-quality sampling described above: it provides the spatial and elevation framework needed to interpret drainage patterns, tidal influence, and probable contaminant-transport pathways around the sampled point, and it establishes fixed, re-occupiable stations for any future spatially resolved monitoring programme. It is not, in this reconnaissance-level study, a second source of water-quality data - only the Base/TBM1 station was sampled and analysed for physicochemical and microbiological parameters. This distinction, which the current dataset had left implicit, is stated explicitly here and reflected consistently in Table 3 and the discussion in Section 3.1.

i. Reduced Level

$$RL = RL_{BM} + BS - FS \quad (1)$$

where RL_{BM} is the reduced level of the benchmark (m), BS is the back-sight reading (m), and FS is the fore-sight reading (m).

ii. Horizontal Distance

$$D_{ij} = \sqrt{(E_j - E_i)^2 + (N_j - N_i)^2} \quad (2)$$

where D_{ij} is the horizontal distance between stations i and j (m), and E and N are the Easting and Northing coordinates of each station.

iii. Elevation Difference

$$\Delta h_{ij} = Z_j - Z_i \quad (3)$$

iv. Slope Distance

$$S_{ij} = \sqrt{D_{ij}^2 + (\Delta h_{ij})^2} \quad (4)$$

Analytical Procedures

All physicochemical analyses were performed at FRIMO Analytical Consults, Calabar, a laboratory registered with the Nigerian Institute of Science Laboratory Technology (NISLT), following methods described in Standard Methods for the Examination of Water and Wastewater (APHA, AWWA, & WEF, 2023). Table 2 lists the physical parameters and their analytical principles; the chemical and microbiological methods, with their governing equations, are set out in Sections 2.4.1 and 2.5.

Table 2: Physical Parameters and Analytical Methods

Parameter	Method	Analytical Principle
Colour	Colorimetric	Platinum-cobalt (Pt-Co) comparison
Odour	Organoleptic	Sensory observation
Temperature	Digital thermometer	Direct thermometric reading
Turbidity	Nephelometric	Light-scattering detection
Conductivity	Conductivity meter	Electrical conductance measurement
pH	Digital pH meter	Hydrogen-ion activity



Chemical Analysis

i. Dissolved Oxygen (Winkler Method). Dissolved oxygen was determined by the Winkler iodometric method: following acidification with sulfuric acid, liberated iodine was titrated against standardised sodium thiosulfate (APHA, AWWA, & WEF, 2023).

$$DO \text{ (mg/L)} = (V_t \times N \times 8,000) / V_s \quad (5)$$

where V_t is the volume of thiosulfate titrant (mL), N is its normality (eq/L), and V_s is the sample volume (mL).

ii. Alkalinity. Total alkalinity, associated principally with bicarbonate, carbonate, and hydroxide ions, was determined by titration with a standardised acid to a defined endpoint.

$$Alk \text{ (mg/L as CaCO}_3\text{)} = (V_t \times N \times 50,000) / V_s \quad (6)$$

iii. Total Hardness. Total hardness, expressed as calcium carbonate equivalent and associated principally with dissolved calcium and magnesium, was determined by complexometric (EDTA) titration.

$$TH \text{ (mg/L as CaCO}_3\text{)} = (V_t \times N \times 50,000) / V_s \quad (7)$$

iv. Biochemical Oxygen Demand (BOD₅). BOD₅ represents the dissolved oxygen consumed by micro-organisms during the biological degradation of organic matter over five days under controlled incubation.

$$BOD_5 \text{ (unseeded)} = DO_i - DO_f \quad (8)$$

$$BOD_5 \text{ (seeded)} = [(D_1 - D_2) - (B_1 - B_2)f] / P \quad (9)$$

where D_1 and D_2 are the initial and final DO of the diluted sample, B_1 and B_2 are the initial and final DO of the seed control, f is the seed correction factor, and P is the decimal fraction of sample in the diluted bottle.

v. Chloride. Chloride was determined by titrimetric (argentometric) analysis.

$$Cl^- \text{ (mg/L)} = (V_t \times N \times 35,450) / V_s \quad (10)$$

vi. Sulfate. Sulfate was determined by the barium chloride turbidimetric method, in which sulfate ions react with barium ions to form barium sulfate whose turbidity is read against a calibration curve.

$$SO_4^{2-} \text{ (mg/L)} = f(A) \quad (11)$$

where A is the measured turbidance and f is the calibration function derived from sulfate standards.

vii. Trace Metals. Iron, zinc, manganese, lead, and cadmium were determined by Atomic Absorption Spectrophotometry (AAS) after appropriate sample digestion, against instrument calibration standards.

$$C_m \text{ (mg/L)} = f(A) \quad (12)$$

where A is the measured absorbance and f is the calibration function established from standard solutions.

Microbiological Analysis

Microbiological analysis used the membrane-filtration technique: a measured volume of water was passed through a sterile membrane filter, which was then placed on an appropriate culture medium and incubated under specified conditions (APHA, AWWA, & WEF, 2023).

$$CFU/100 \text{ mL} = (C \times 100) / V_f \quad (13)$$



where C is the number of colonies counted and Vf is the volume of sample filtered (mL).

Comparative Standards Framework

Because this study serves two distinct audiences - public-health and potable-water assessment on one hand, and construction-water suitability on the other - two separate benchmark sets are applied deliberately, rather than a single potable-water standard being extended, without justification, to a construction-water question.

For general chemical and microbiological safety, results are compared against the Nigerian Industrial Standard (NIS) limits reproduced on the laboratory's certificate of analysis. For construction-water suitability, Nigeria has no dedicated national mixing-water standard, and the recognised international mixing-water standards (BS EN 1008 and ASTM C1602) centre their acceptance criteria on comparative mortar performance - initial and final setting time and compressive strength relative to a distilled-water control - rather than on a single fixed table of chemical limits. Accordingly, this study does not attempt to reproduce a borrowed numeric chemical-limits table for construction-water screening; instead, Section 3.2 compares the measured chemistry against the NIS limits only, and Section 3.3 is explicit that a firm construction-water suitability determination requires the mortar/concrete performance testing that BS EN 1008 or ASTM C1602 themselves prescribe, which was beyond the scope of this reconnaissance-level study.

Engineering Indices

Four screening-level indices were computed from the measured chemistry to translate the raw results into an engineering aggressiveness and pollution context. They are presented as first-pass indicators, not as a substitute for direct concrete-performance testing, a distinction reiterated in Section 3.3.

i. Aggressiveness Index (AI)

The Aggressiveness Index, adapted from the Langelier Saturation Index as a commonly used indicator of the corrosive tendency of water, is given by:

$$AI = pH + \log_{10}(A \times H) \quad (14)$$

where A is total alkalinity (mg/L as CaCO₃) and H is calcium hardness (mg/L as CaCO₃). Using the measured alkalinity (15.00 mg/L) and total hardness (16.50 mg/L) as a proxy for calcium hardness:

$$AI = 5.00 + \log_{10}(15.00 \times 16.50) = 5.00 + \log_{10}(247.5) = 5.00 + 2.39 = 7.39 \quad (15)$$

Under a commonly used aggressiveness classification (AI < 10.0: highly/very aggressive; 10.0-12.0: moderately aggressive; > 12.0: non-aggressive), a value of 7.39 places the Kwa River sample in the highly aggressive category, driven principally by its low pH and low alkalinity. This corrects the earlier working figure of AI = 6.18, which had omitted the hardness term from the log argument; the corrected value strengthens, rather than weakens, the paper's conclusion that the water is chemically aggressive.

ii. Turbidity-Based Pollution Index

$$PI_T = [(CT - ST) / ST] \times 100 \quad (16)$$

where CT is the observed turbidity and ST is the permissible turbidity (NIS: 5 NTU).

$$PI_T = [(29.40 - 5) / 5] \times 100 = 488\% \quad (17)$$

This corrects an inconsistent figure of 588% that had appeared in an earlier summary of the same result; 488% is the value the stated formula and inputs actually produce, and it is the figure used consistently throughout this revised paper.



iii. Water Quality Index (WQI)

The weighted arithmetic Water Quality Index (Tyagi et al., 2013) is given for reference as:

$$WQI = \Sigma(qi \cdot wi) / \Sigma(wi) \quad (18)$$

where qi is the quality rating of parameter i and wi is its weighting factor. A full WQI computation requires an agreed weighting scheme across all measured parameters and is recommended as part of the expanded, multi-point monitoring programme proposed in Section 4.2, rather than computed from a single composite sample here.

iv. Corrosion Potential (CP)

$$CP = (Cl^- + 2 \cdot SO_4^{2-}) / Alk \quad (19)$$

$$CP = [16 + 2(26.2)] / 15 = 68.4 / 15 = 4.56 \quad (20)$$

The elevated value reflects the relatively low alkalinity of the water and reinforces the corrosion concern already indicated by the Aggressiveness Index.

v. Concrete Durability Screening Ratio (R)

$$R = (SO_4^{2-} \times pH) / Alk \quad (21)$$

$$R = (26.2 \times 5) / 15 = 8.73 \quad (22)$$

Interpretation: a moderate screening-level indication of sulfate- and acid-related concrete degradation risk. As with the other indices in this section, R is a chemistry-based screen, not a substitute for the mortar/concrete performance tests specified by BS EN 1008 or ASTM C1602 (see Section 3.3).

RESULTS AND DISCUSSION

Hydrographic Survey Results

Table 3 presents the coordinates, reduced levels, and interpretation of the Base/TBM1 sampling station and the six survey reference points (P1-P6).

Table 3: Hydrographic Survey Data

Point	Description	Northin g (N)	Eastin g (E)	Elevatio n (Z, m)	Interpretation
Base/TBM 1	Primary sampling/construction intake point	552980	423962	3.249	Sampled and analysed station (this study)
P6	Fixed reference point	553000	423978	3.216	Upstream monitoring reference
P5	Reference point 5	552996	423982	3.154	Upstream, right bank
P4	Reference point 4	552973	423961	3.089	Downstream, left bank
P3	Reference point 3	552978	423966	3.156	Mid-stream, downstream
P2	Reference point 2	552995	424112	0.345	Tidal flat / construction spoil area
P1	Reference point 1	552994	424012	0.336	Tidal flat / construction spoil area

The six reference points and the sampled station were not all analysed for water chemistry in this campaign - only the Base/TBM1 station was sampled - but their coordinates and elevations still carry interpretive value. P1 and P2, at reduced levels of 0.336 m and 0.345 m respectively, sit roughly 2.8-2.9 m lower than the upstream stations P3-P6 and the Base station itself, and both are described as tidal-flat/construction-spoil ground. This low-lying, tidally inundated terrain is consistent with a plausible pathway by which surface runoff, spoil leachate, and tidal ingress could mobilise sediment and organic matter into the river channel and toward the sampled intake point, offering a physically grounded explanation for the high turbidity and low dissolved oxygen recorded at the Base station, rather than treating those results as unexplained anomalies. Confirming this pathway, however, would require water-quality samples actually taken at P1-P6 under different tidal and seasonal conditions, which this reconnaissance-level study did not include; Section 4.2 recommends this as the next step.

Laboratory Results

Laboratory analysis was conducted at FRIMO Analytical Consults, Calabar (NISLT-registered), Batch No. 05/10/24WPLRW, certified 5 October 2024 by the laboratory's chief analyst. Tables 4-7 present the physicochemical, chemical, trace-metal, and microbiological results, each compared against the NIS potable-water limit.

Table 4: Physical Parameters

Parameter	Unit	NIS Limit	Observed	Compliance
Colour	HU	3	3.16	Marginal
Temperature	°C	Ambient	27.5	-
Turbidity	NTU	5	29.4	Non-compliant
Conductivity	µS/cm	1,000	30.1	Compliant
pH	-	6.5-8.5	5	Non-compliant

Table 5: Chemical Parameters

Parameter	Unit	NIS Limit	Observed	Compliance
BOD5	mg/L	35	3.26	Compliant
Chloride	mg/L	100	16	Compliant
Nitrate (NO ₃ ⁻)	mg/L	45	18.4	Compliant
Nitrite (NO ₂ ⁻)	mg/L	0.1	0.21	Non-compliant
Sulfate (SO ₄ ²⁻)	mg/L	100	26.2	Compliant
Total Dissolved Solids	mg/L	500	14	Compliant
Total Hardness	mg/L	100	16.5	Compliant
Alkalinity	mg/L	200	15	Compliant
Dissolved Oxygen	mg/L	14	2.82	Non-compliant

Table 6: Trace Metals

Metal	Unit	NIS Limit	Observed	Compliance
Iron (Fe)	mg/L	0.3	0.21	Compliant
Zinc (Zn)	mg/L	0.05	0.02	Compliant
Manganese (Mn)	mg/L	20	6.52	Compliant
Lead (Pb)	mg/L	0.003	0	Compliant

Cadmium (Cd)	mg/L	0.001	0	Compliant
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Table 7: Microbiological Parameters

Parameter	NIS Limit	Result	Compliance
Total Viable Count	<1,000 CFU/mL	50 CFU/mL	Compliant
Escherichia coli	Nil	Nil	Compliant
Faecal coliform	Nil	Nil	Compliant
Total coliform	10 CFU/100 mL	18 CFU/100 mL	Non-compliant

Reading the Results Toward Construction Suitability

Read purely on the chemistry in Tables 4-7, the water's chloride, sulfate, and dissolved-solids content are modest and would not, on their own, be expected to disqualify it from concrete mixing use; it is the acidity, low alkalinity, high turbidity, and coliform presence that drive the non-compliant assessment, together with the durability concern captured by the corrected Aggressiveness Index in Section 2.7. This is a chemistry-based reading only: as Section 2.6 makes clear, a firm construction-water suitability determination still rests on the comparative mortar/concrete performance testing prescribed by the governing mixing-water standards, which this study did not carry out.

Engineering Indices and Concrete-Performance Caveat

The Aggressiveness Index (7.39, highly aggressive), turbidity-based pollution index (488%), and corrosion potential (4.56) together describe water that is chemically hostile to steel reinforcement and to long-term cement-paste stability, largely because of its acidity and low buffering capacity rather than its salt content. It is important, however, to be precise about what these indices can and cannot show. They are chemistry-based screening tools, adapted in most cases from potable-water and pipeline-corrosion literature rather than derived specifically for concrete performance, and none of them substitutes for the compressive-strength and setting-time comparisons against a distilled-water control that mixing-water standards actually prescribe for qualifying a water source for concrete mixing. This study did not cast and test mortar or concrete specimens using Kwa River water, so the specific deterioration mechanisms flagged in Section 1 - sulfate attack, reinforcement corrosion, cement-paste dissolution - are presented here as plausible, chemistry-consistent risks rather than as demonstrated outcomes. Section 4.2 recommends this confirmatory testing as the logical next step before the water is either approved or ruled out for construction use.

DISCUSSION OF RESULTS

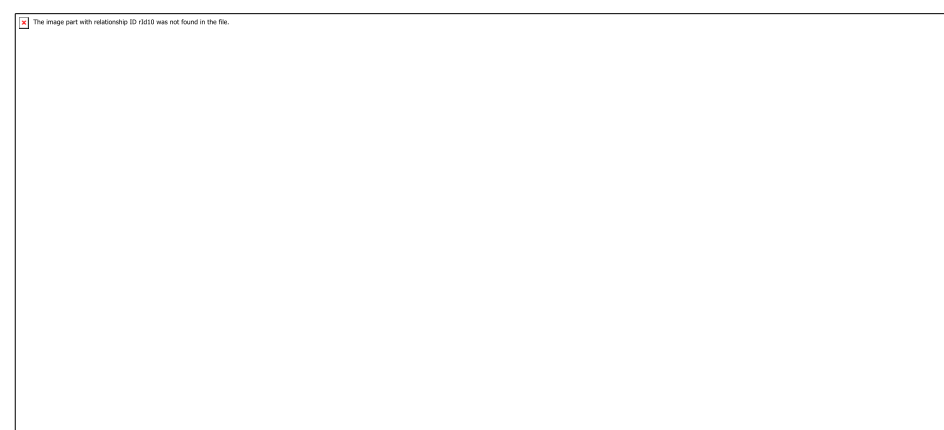


Figure 2 (a-d). Kwa River physical, chemical, trace-metal, and microbiological results against NIS standards.



Physical quality (Fig. 2a). The turbidity of 29.40 NTU indicates a substantial suspended-solids load, plausibly linked to the surface runoff and tidal re-suspension discussed in Section 3.1, and it poses practical challenges for naval-vessel intake filtration as well as for concrete-mix water clarity. The pH of 5.00 marks the water as acidic and chemically aggressive, with the corrosion and durability implications set out in Sections 2.7 and 3.3.

Chemical quality (Fig. 2b). Dissolved oxygen at 2.82 mg/L is low enough to suggest limited aerobic capacity and a tendency toward anaerobic microbial activity in the sediment-water interface. Nitrite at 0.21 mg/L exceeds the NIS limit and points to active nitrification or an anthropogenic nitrogen source upstream. Alkalinity of 15 mg/L confirms a soft, poorly buffered water with limited capacity to resist further acidification, which is precisely the property the corrected Aggressiveness Index in Section 2.7 captures.

Trace metals (Fig. 2c). All measured trace metals - iron, zinc, manganese, lead, and cadmium - were within NIS limits, with manganese the highest relative to its standard. Trace-metal loading is not, on this evidence, a primary concern at this location, in contrast to the acidity, turbidity, and microbial results.

Microbiological quality (Fig. 2d). Total coliform at 18 CFU/100 mL exceeds the 10 CFU/100 mL NIS limit, indicating a fecal-contamination risk consistent with anthropogenic activity, organic pollution, or sediment-associated bacterial reservoirs, though, as noted in Section 2.2.2, this figure should be read alongside the extended holding time before analysis.

SUMMARY OF FINDINGS

Table 9: Summary of Key Findings

Key Finding	Implication
Acidic pH (5.00)	Chemically aggressive water; elevated potential for metal corrosion and concrete deterioration
High turbidity (29.40 NTU)	Excessive suspended matter; filtration or equivalent treatment required before use
Elevated nitrite (0.21 mg/L)	Indicates possible pollution; potential health and ecological concern
Total coliform present (18 CFU/100 mL)	Microbiological contamination; treatment required; result affected by extended holding time
Aggressiveness Index = 7.39 (corrected)	Highly aggressive water; protective measures and confirmatory testing needed for concrete work

Construction Suitability Matrix

Table 10: Construction Suitability Matrix

Engineering Application	Suitability	Recommended Action
Concrete mixing water	Poor	Treatment required (pH adjustment, filtration); confirm with mortar strength/setting-time tests
Soil compaction	Marginal	Conditional use with regular monitoring
Dust suppression	Acceptable	Limited use is acceptable
Curing water	Unsuitable	Avoid; seek an alternative source
Cooling water	Poor	Corrosion risk; treatment or an alternative source required



STUDY LIMITATIONS

In the interest of transparent, reproducible reporting, five limitations of this reconnaissance-level study are stated explicitly:

- 1. Single sampling event.** Only one composite sample was collected, at one location, on one date and tidal state. The results describe conditions on 25 September 2024 and should not be read as characterising the river's seasonal or tidal range. Statistical comparison across the six survey points (P1-P6) was therefore not attempted, since those points were surveyed for elevation and coordinates but not sampled for water chemistry in this campaign.
- 2. Extended microbiological holding time.** An approximately eight-day gap between collection and analysis, against a recommended 24-hour holding time for microbiological work, means the coliform result should be treated as indicative rather than precise (Section 2.2.2).
- 3. No borrowed numeric construction-water table.** In the absence of a Nigerian mixing-water standard, this study deliberately avoided substituting a foreign numeric chemical-limits table for construction-water screening (Section 2.6); construction-water suitability is instead discussed qualitatively against the measured chemistry, which is a more conservative approach but does not itself constitute a pass/fail determination.
- 4. No direct concrete-performance testing.** No mortar or concrete specimens were cast and tested with Kwa River water. The Aggressiveness Index, corrosion potential, and durability screening ratio in Section 2.7 are chemistry-based indicators of risk, not measured outcomes (Section 3.3).
- 5. Detection limits and instrument QA/QC not disclosed.** The laboratory's certificate of analysis reports results and its own NIS reference values but does not state instrument detection limits or a formal quality-assurance/quality-control protocol beyond its NISLT registration and signed chief-analyst certification. Disclosure of detection limits is recommended for all future analytical rounds on this project.

CONCLUSION AND RECOMMENDATIONS

Conclusion

On the evidence of this single sampling event, untreated Kwa River water at the Naval Base intake point is unsuitable for direct engineering, naval, or potable use without treatment. Its acidity, low alkalinity, high turbidity, and coliform presence are the parameters driving that conclusion, while its trace metal, chloride, and sulphate content are within the NIS potable limit and are not, on their own, expected to be a major concern for concrete mixing use. Minimum treatment before any of the uses considered in Table 10 would include pH neutralisation, turbidity removal, and disinfection; corrosion inhibition would additionally be needed wherever the water contacts steel reinforcement or naval hull components. A firm determination of construction suitability, as distinct from this chemistry-based screening result, still depends on the mortar/concrete performance testing recommended below.

Recommendations

- i.** For Naval/Amphibious Operations: Install onboard filtration and pH-adjustment systems where river water is drawn for equipment or training use, and monitor hull and equipment corrosion rates over time.
- ii.** For Construction: Source alternative water for concrete curing and mixing wherever practicable. Where Kwa River water must be used, apply lime treatment for pH and alkalinity adjustment, and confirm suitability with the setting-time and compressive-strength tests specified in BS EN 1008 or ASTM C1602 before committing it to structural work.
- iii.** For Sampling Design: Extend the single-point reconnaissance campaign reported here into a replicate, multi-point programme that actually samples water chemistry at the P1-P6 survey stations already established



(Section 3.1), across at least one full tidal cycle and both wet and dry seasons, so that spatial and temporal variation can be assessed statistically rather than inferred from elevation data alone.

iv. For Laboratory Practice: Complete microbiological analysis within the 24-hour holding time recommended by Standard Methods, and request that the laboratory report instrument detection limits and its quality-assurance/quality-control procedure alongside each certificate of analysis.

v. For Environmental Management: Investigate upstream pollution sources contributing to the elevated nitrite and coliform results, using the hydrographic survey stations as a starting framework for source-tracking.

vi. For Future Monitoring: Establish a quarterly monitoring programme tracking pH, turbidity, dissolved oxygen, nitrite, and microbial indicators at the Base station and, once sampled, at the P1-P6 network.

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