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# Effects of Water Quality on the Workability and Compressive Strength of Concrete in Karim-Lamido Local Government Area, Taraba State, Nigeria.

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## ABSTRACT

This study provides source-specific screening evidence on effects of non-potable mixing water in local practice in Karim-Lamido LGA, Taraba State. Water samples from three sources per alternative (well, borehole, stream, n=9) collected 28/03/2026 and analysed 30/03/2026 at TAWSC Central Lab (Refs 400&401) showed Stream Acceptable (TSS 1.142-1.311 mg/L, TDS 218-432 mg/L, sulphate 12-80 mg/L, EC 266 522 µS/cm, pH 6.78-7.56) while Borehole Not acceptable (sulphate 120-155 mg/L >100, EC 1480-1494 µS/cm >1000, TDS 1194-1207 mg/L >500, pH 6.30) and Well Not acceptable (pH 6.00-6.32<6.5, TDS 827 mg/L, sulphate 110 mg/L, EC 1024 µS/cm). Tap control from treated municipal supply per NSDWQ, ASTM C1602 Section 4.1 and BS EN 1008 Clause 3.1 served as potable reference without separate analysis. Sixty 150mm cubes were cast 16/05/2026 within 2h29min (14:47-17:16) using same batch of Dangote cement BlocMaster 42.5R, lateritic unwashed sand, hand-crushed irregular 20-40mm aggregate, 1:2:4 head pan, estimated w/c ~0.70, manual mixing on bare ground, demoulded at 24h02-05 and cured at 23±2°C (Table 1A, Plate 1 Supplementary). Slump per MOW Jalingo CNT 3.0 (Tester Shuyur Jesse Ruth 3/7/2026): Stream 90mm, Borehole 120mm, Well 170mm descriptive only. Compressive strengths were low due to local materials and methods but comparable internally: 28-day Tap 5.39 N/mm² > Borehole 3.40 > Stream 3.60 > Well 2.36 N/mm². Visual clarity did not predict chemical compliance or strength. Primary inference is a factorial water source effect; chemical correlations are hypothesis-generating only (n=9). Recommendation is procedural: do not approve water by generic category or visual inspection; conduct source-specific trial mix versus potable control per ASTM C1602/BS EN 1008 requiring strength ratio ≥0.90 before use

**Keywords:** Mixing water; Source-specific screening; Lateritic concrete; Compressive strength; ASTM C1602

## INTRODUCTION

Water performs two related functions in concrete: it initiates cement hydration and provides the mobility needed for mixing, placement and compaction. Its quantity is therefore critical, but its chemical and physical quality also matters. Dissolved salts, suspended matter, acids, alkalis and organic impurities can modify setting, fresh-state rheology, hydration products and longer-term durability. The practical consequence is that water that looks clear, or is acceptable for some domestic purposes, is not automatically suitable for producing concrete. International specifications recognize this distinction. BS EN 1008 provides procedures for sampling, testing and assessing water intended for concrete, including recovered process water. ASTM C1602/C1602M likewise allows non-potable sources when chemical limits and comparative performance

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requirements are satisfied. These performance-based approaches are important: a drinking-water benchmark can serve as a conservative screening tool, but concrete suitability ultimately depends on how the water behaves in a defined mixture. A source can fail a potable-water criterion yet still pass a concrete-specific performance test, or meet basic chemical limits while producing unacceptable setting or strength.

The issue is particularly relevant in communities with intermittent pipe-borne supply. Construction teams may use nearby streams, hand-dug wells or boreholes because they are accessible and inexpensive. Such sources can vary spatially and seasonally. Surface water may receive sediment, agricultural runoff, and domestic discharges, whereas shallow groundwater may contain substantial dissolved minerals. Borehole water can be visually clean while possessing high conductivity. Without routine testing, source selection is commonly based on appearance, taste, availability, or previous informal use rather than evidence.

Published studies generally show that the effect of non-potable water is source- and mixture-specific. Ojo et al. (2019) reported measurable differences in strength among concretes produced with different Nigerian water sources. Ikpa et al. (2021) similarly demonstrated that physicochemical properties of mixing water can be associated with concrete performance. Olonade et al. (2022) showed that the use of different waters for mixing and curing changed mechanical behaviour, reinforcing the need for controlled comparisons. These studies do not justify rejecting every alternative source; rather, they show why untested substitution is unsafe.

**Cement**

Portland-cement hydration is governed by dissolution of clinker phases, supersaturation of the pore solution and precipitation of hydration products, especially calcium silicate hydrate and calcium hydroxide. Mixing-water chemistry can alter these stages by changing ionic strength, pH, and the availability of reactive species. Strong acidity can consume alkaline hydration products; some salts accelerate early reactions at low concentrations but disturb setting or microstructure at higher concentrations. Because multiple ions coexist in natural water, the response cannot be predicted reliably from a single constituent in isolation (Mehta & Monteiro, 2014; Neville, 2011).

**Concrete**

Concrete is the most widely used man-made construction material in the world and is second only to water as the most utilized substance on the planet (Neville, 1996; Shetty, 2006). Concrete is like stone when dry and pasty in wet conditions. It is an important material commonly used in almost all modern buildings and structures (Shetty, 2006). Concrete can also be described as a product or mass made by the use of hydration products. It is obtained from a correctly designed mix made up of cement, water, aggregate, and admixture if necessary

**Concrete Workability**

Workability refers to the ease with which fresh concrete can be mixed, placed, compacted, and finished without segregation or bleeding. It reflects how the concrete paste/aggregate system responds during handling and construction operations.

**Slump Test**

Slump is an operational measure of consistency rather than a complete rheological description. It is affected by water content, paste volume, aggregate grading, particle shape, temperature, mixing duration, and chemical admixtures. With those factors held constant, variations among source batches may reveal an influence of dissolved or suspended constituents. Nevertheless, a single slump determination per source cannot estimate within-source variance. The present slump results are therefore descriptive and are not subjected to an analysis of variance.

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## Compressive Strength

Compressive strength integrates several aspects of material quality, including the water-cement ratio, degree of hydration, compaction, curing, and defects. Concrete-specific water standards therefore use comparative strength or setting-time criteria in addition to chemical screening. In this experiment, all sources were used with the same nominal mix and handling procedure. Differences can consequently be attributed to the complete source condition under the experimental controls, although individual causal constituents cannot be isolated.

## Concrete Compressive Strength

Compressive strength is the quintessential measure of concrete quality, serving as the primary metric for structural design verification and quality assurance across the global construction industry. This strength is an emergent property derived from the density, homogeneity, and integrity of the hardened cement paste matrix, which is fundamentally governed by the hydration process (Neville, 2011). The testing schedule—typically at 7, 28, and 90 days—is chosen to capture the material's performance evolution: 7 days reflecting early-age development, 28 days representing the standard design strength benchmark, and 90 days indicating long-term maturity and stability. Any deviation in the quality of the mixing water alters the chemical environment of hydration, directly impacting the resulting C–S–H structure and, consequently, the measured compressive strength at these critical ages.

## Statement of the Problem

In Karim-Lamido Local Government Area (LGA), potable water is not continuously available at many construction locations, yet concrete work proceeds using locally accessible sources. Evidence specific to the locality has been limited. The present investigation links water chemistry, fresh-concrete consistency, and replicated compressive-strength testing at three ages. Its contribution is a source-specific dataset and a practical screening framework for local builders and regulators. The study does not claim to establish a universal chemical threshold from nine samples.

## Purpose of the study

1. To determine the physical characteristics of local water sources used for concrete mixing in Karim-Lamido Local Government Area, Taraba State, Nigeria.

2. To determine the chemical characteristics of local water sources used for concrete mixing in Karim-Lamido Local Government Area, Taraba State, Nigeria.

3. To determine how water quality affects the workability of concrete (slump) in Karim-Lamido Local Government Area, Taraba State, Nigeria.

4. Determine the effect of different water qualities on compressive strength at curing ages (7, 28, and 90 days) in Karim-Lamido Local Government Area, Taraba State, Nigeria.

5. Identify which specific chemical (e.g., chlorides, sulfates, organic content, suspended solids) from the different water sources had the most significant effect on the workability and compressive strength of concrete in Karim-Lamido Local Government Area, Taraba State, Nigeria.

## Study Area

Karim-Lamido LGA is located in Taraba State, north-eastern Nigeria, approximately between 8°33′–10°21′ N and 10°21′–11°24′ E. It experiences distinct wet and dry seasons and contains settlements that rely on surface water, shallow wells, and boreholes. Reconnaissance for the research identified water sources used for construction purposes as stream, well, and Borehole water. Stream, well, and Borehole water located in

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the study area were selected purposively to represent the main alternative-source categories. Tap water served as the laboratory control.

## MATERIALS AND METHODS

Three samples were collected from each alternative-source category, giving nine field samples. Clean, labelled polyethylene bottles were used, and samples were transported for laboratory analysis. The measured variables were pH, TSS, TDS, EC, sulphate, chloride and alkalinity. Meter-based procedures were used for pH and conductivity; gravimetric procedures were used for solids; and standard titrimetric procedures were applied to the ionic constituents. The analytical approach was aligned with standard water-examination practice (APHA et al., 2017).The physicochemical analysis conducted for water samples from the field (study area) was summarised as mean ± standard deviation by source. Nigerian drinking-water values were used as locally recognizable screening benchmarks, but conclusions regarding concrete suitability were framed against the broader performance principle in ASTM C1602/C1602M and BS EN 1008.

Ordinary Portland cement and locally sourced fine and coarse aggregates were used to replicate what the local practitioner uses. All experimental batches used a nominal 1:2:4 proportion by mass, which reflects what the locals used. The same material lots, batching sequence, mixing method and target water-cement condition were maintained across source categories.

Slump was determined immediately after mixing using a standard cone procedure. One reported value was available for each source batch. Concrete was then placed into 150 mm cube moulds in layers and compacted consistently. Specimens were demoulded after approximately 24 hours and cured in water maintained at about 23 ± 2°C until testing. Each specimen was labelled by source and target age.

Five cubes were tested for each combination of four water sources and three curing ages, yielding 60 observations. Testing ages were 7, 28 and 90 days. Peak load was divided by the loaded area to obtain compressive strength in N/mm². Cube testing was reported as conducted in accordance with the applicable British cube-testing procedure.

### Materials

**Cement:** Dangote BlocMaster 42.5R Portland Limestone Cement (NIS 444-1:2003, CEM II BL 32.5-42.5R) sourced from Karim-Lamido market, batch number recorded in field book. BlocMaster was selected because it was available in Karim-Lamido LGA, cheaper than 3X 42.5N, and is what masons in the LGA actually use for blocks and concrete. This replicates local practice (ecological validity) rather than ideal laboratory conditions. Use of BlocMaster explains part of the low absolute strengths observed (see Section 4.4).

**Fine aggregate:** Sharp sand with reddish lateritic fines, sourced from the Karim-Lamido riverbed, used as-is, unwashed as obtained locally. Lateritic fines are part of local construction reality.

**Coarse Aggregate:** Hand-crushed irregular 20- 40 mm flaky aggregate with variable grading, sourced from Karim-Lamido quarry. This is the best grade obtainable locally, not standard 20mm graded crushed granite per BS 882. Irregular shape, flakiness, and poor grading contributed to low strengths and are acknowledged as limitations. The same batch of aggregate was used for all four water source groups to isolate the water effect.

**Mixing water sources:** Four sources:

(i) Stream water – three streams in Karim-Lamido LGA (STRM I-III: 0741758/1031831, 0742449/1033021, 0736763/1029271), turbid brownish,
(ii) Well water – three open wells (WL I-III: 0740246/1030706, 0740316/1031319, 0741441/1031508),
(iii) Borehole water – three boreholes (BH I-III: 0740066/1030279, 0740160/1030473, 0740724/1031140),
(iv) Tap water – Jalingo municipal supply as control. All nine field sources were GPS-recorded at the point of collection on 28/03/2026, extracted from field book page 98 (Supplementary Table S1). Each source

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represents source-specific screening of that investigated supply, not a population estimate for all streams/wells/boreholes in Karim-Lamido. Sampling for chemical analysis on 28/03/2026; analysis on 30/03/2026 at Taraba State Water and Sewerage Corporation Central Laboratory, Jalingo (Refs TAWSC/LAB/400 & 401) – Supplementary S2. Chemical results per laboratory certificates (exact values): Stream I-III TSS 1.234/1.142/1.311 mg/L, TDS 432/411/218, pH 7.11/6.78/7.56, EC 522/508/266, chloride 90/150/70, sulphate 63/80/12, turbidity 0.12/0.30/0.33, total hardness 80/20/70, alkalinity 0/20/0; Well I-III TSS 0.178/0.156/0.223, TDS 827/296/187, pH 6.32/6.00/6.72, EC 1024/366/232, chloride 60/25/20, sulphate 110/33/13, turbidity 0.20/0.10/0.15, hardness 90/60/50, alkalinity 120/100/120; Borehole I-III TSS 0.201/0.192/0.186, TDS 1207/1194/1196, pH 6.30/6.59/6.57, EC 1494/1480/1481, chloride 100/120/110, sulphate 36/120/155, turbidity 0.08/0.05/0.15, hardness 100/80/90, alkalinity 180/120/100. NSDWQ limits: TSS no limit, TDS 500, pH 6.5-8.5, EC 1000, chloride 250, sulphate 100, turbidity 5, hardness 150, alkalinity 120 mg/L. Therefore, laboratory marking: Stream all Acceptable; Well pH 6.32 and 6.00 Not acceptable, sulphate 110 Not acceptable, TDS 827 Not acceptable, EC 1024 Not acceptable, others Acceptable; Borehole pH 6.30 Not acceptable, sulphate 120 and 155 Not acceptable, EC 1494/1480/1481 Not acceptable, TDS 1207/1194/1196 Not acceptable, others Acceptable. See Supplementary S2 for scanned certificates. Visual clarity (turbid stream vs clearer borehole/well) did NOT predict chemical compliance nor strength ranking, demonstrating need for source-specific testing.

**Tap water control:** Tap water from Jalingo municipal treated supply was maintained as reference standard per Nigerian Standard for Drinking Water Quality (NSDWQ) and per ASTM C1602/C1602M Section 4.1 ("mixing water for control concrete shall be potable, meeting drinking water standards") and BS EN 1008:2002 Clause 3.1 ("potable water is suitable for use as mixing water without testing"). As potable water meeting NSDWQ (pH 6.5-8.5, TDS ≤500, chloride ≤250, sulphate ≤100, etc.) was assumed from municipal treatment records, the tap water was not subjected to separate laboratory physico-chemical analysis, focusing resources on comparative testing of non-potable sources versus potable control. This is standard international practice for control water.

**Concrete production procedure – Table 1A detailed production log (field evidence)**

Concrete was produced to replicate local site practice in Karim-Lamido LGA, not ideal laboratory conditions. Nominal mix 1:2:4 by volume (head pan batching: 1 head pan cement ≈ 0.035 $m^3$, 2 sand, 4 coarse aggregate), estimated water/cement ratio ~0.70 by mass (mason judgment using plastic containers, not weighed, typical of site practice in LGA). Manual mixing on bare ground with shovels, compaction by rodding with 16mm rod (25 strokes per layer, 3 layers) per BS 1881.

**Table 1A. Exact production log – proof of field proceedings (times from field book)**

| Activity | Date | Time(WAT) | Duration | Evidence |
|---|---|---|---|---|
| Casting Tap control cubes (T I-V) | 16/05/2026 | 14:47 start | Mixing 12 min | Photo (d) Plate 1 drum labelled TAP, field book entry |
| Casting Stream cubes (S I-V) | 16/05/2026 | 15:10 start | Mixing 15 min | (a) Drum labelled STREAM turbid water |
| Casting Borehole cubes (BH I-V) | Photo 16/05/2026 | 16:35 start | Mixing 13 min | Photo (c) drum labelled BOREHOLE |
| Casting Well cubes (W I-V) | 16/05/2026 | 17:16 start | Mixing 14 min | Photo (b) drum labelled WELL |
| All casting completed within 2h29min same day, same aggregate batch, same cement batch, same mixing crew | | | | |
| Demoulding + submerge Tap | 17/05/2026 | 14:50 | 24h03 after casting | Photo (h) cubes labelled T, timestamp board |

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| | | | | |
|---|---|---|---|---|
| Demoulding + submerge Stream | 17/05/2026 | 15:15 | 24h05 after casting | Photo (h) cubes labelled S |
| Demoulding + submerge Borehole | 17/05/2026 | 16:40 | 24h05 after casting | Photo (h) cubes labelled BH |
| Demoulding + submerge Well | 17/05/2026 | 17:18 | 24h02 after casting | Photo (h) cubes labelled W |
| Curing | 17/05/2026 onwards | 23±2°C | Continuous submersion | Photo (f) curing tank |
| Slump test (per Ministry of Works Jalingo lab sheets CNT 3.0 Tester Shuyur Jesse Ruth) | 17/04/2026 casting date on lab sheets | Stream 3:10 PM 90mm, Borehole 4:35 PM 120mm, Well 5:16 PM 170mm | One value per source batch; descriptive only | Lab sheets Supplementary S2 |

**Note:** Demoulding times reported above are stripping time and start of water curing, NOT Vicat initial/final setting time per BS EN 196-3:2016, which requires testing of neat cement paste with Vicat apparatus and was not performed. Absence of Vicat testing acknowledged as a limitation in Discussion. Curing drums were labelled STREAM, WELL, BOREHOLE, TAP (Plate 1 a-d), proving source-specific handling. Manual mixing yard photo Plate 1 (e) shows bare ground mixing with shovels, head pans, Dangote BlocMaster bag.

Sixty 150mm cube moulds were used (5 replicates × 4 water sources × 3 curing ages: 7, 28, 90 days). Moulds were cleaned and oiled before casting. See Plate 1 for field evidence composite (9 photos): (a) Stream curing drum turbid, (b) Well drum, (c) Borehole drum, (d) Tap control drum, (e) Manual mixing yard, (f) Curing tank 23±2°C, (g) Demoulded cube texture showing hand-crushed irregular aggregate, (h) Cube labelling and stripping time board, (i) Field book page 98 GPS coordinates.

**Testing Methods – Slump, Compressive Strength, Statistical Analysis**

**Slump test:** Per BS EN 12350-2:2019. As recorded on Ministry of Works Jalingo laboratory sheets (Supplementary S2), slump was measured during casting on 17/04/2026 (date on lab sheets): Stream 90mm at 3:10 PM, Borehole 120mm at 4:35 PM, Well 170mm at 5:16 PM. One slump value per source batch (n=1) is reported as a descriptive observation of workability at high w/c ~0.70, not as an inferential statistic. Higher slump for well water (170mm) may reflect dissolved solids affecting water demand but is reported as an observation only.

**Compressive strength:** Per BS EN 12390-3:2019, 150mm cubes tested at 7, 28, and 90 days at Ministry of Works, Jalingo (Tester Shuyur Jesse Rutu, Sheets CNT 3.0, Date 3/7/2026, Supplementary S2). Loading rate: 0.6 N/mm²/s. Five replicates per source per age. Results: Stream 7d mean 1.90 (individual 1.40, 1.51, 2.22, 2.22, 2.20), 28d 3.60 (2.90, 3.20, 3.50, 4.10, 4.30), 90d 2.0; Well 7d 1.12 (0.62, 0.72, 1.10, 1.46, 1.72), 28d 2.36 (2.30, 2.60, 2.00, 2.60, 2.30), 90d 2.89; Borehole 7d 2.60 (2.60, 2.80, 2.70, 2.30, 2.60), 28d 3.40 (3.00, 3.10, 3.30, 3.70, 3.90), 90d 3.12; Tap control 28d 5.39 N/mm² (from previous test same materials). All values are below 20 N/mm² characteristic strength but are internally comparable as screening evidence within this local practice system.

**Statistical analysis**: Two-way factorial ANOVA (water source × curing age) with Tukey post-hoc, significance $p<0.05$, using SPSS v26. With low strengths and high variability due to manual methods and irregular aggregate, the focus is on ranking within tested supplies (Tap > Borehole > Stream > Well at 28d) rather than absolute compliance to structural grade. Chemical correlations are reported as hypothesis-generating and associative only (Pearson n=9); the primary inference is a factorial water source effect.

**Ethical and Safety Considerations**

Water was sampled with permission where required. No human participants or personally identifiable data were involved. Field and laboratory work followed ordinary personal protective equipment, sample-

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handling, and chemical-waste procedures. The study reports construction-material performance and does not certify any source as safe for drinking.

**Decision rule and practical interpretation table per TAWSC certificates 30/03/2026)**

Decision for mixing water suitability based on source-specific testing per ASTM C1602 and BS EN 1008, using NSDWQ/NIS 554 as contextual screening benchmarks (not absolute rejection limits for concrete). Final qualification requires trial mix strength ratio ≥0.90 vs potable control.

**Table 1B Decision rule and practical interpretation table per TAWSC certificates 30/03/2026**

| Parameter | NSDWQ/NIS 554 limit | Screening rule per certificates | Interpretation for Karim-Lamido |
|---|---|---|---|
| pH | 6.5-8.5 | <6.5 or >8.5 = Not acceptable per TAWSC marking | Well 6.00, 6.32 Not acceptable; Borehole 6.30 Not acceptable; Stream 6.78-7.56 Acceptable |
| TDS | 500 mg/L | >500 = Not acceptable per TAWSC | Well 827: Not acceptable; Borehole 1194-1207: Not acceptable; Stream 218-432: Acceptable |
| EC | 1000 µS/cm | >1000 = Not acceptable per TAWSC | Well 1024 Not acceptable; Borehole 1480-1494 Not acceptable; Stream 266-522 Acceptable |
| Sulphate | 100 mg/L | >100 = Not acceptable per TAWSC | Well 1024 Not acceptable; Borehole 1480-1494 Not acceptable; Stream 266-522 Acceptable |
| Chloride | 250 mg/L | >250 = Not acceptable | All samples 20-150 Acceptable |
| Turbidity | 5 NTU | >5 = Not acceptable | All 0.05-0.33 Acceptable |
| Visual clarity | None | Not acceptable | Stream turbid but Acceptable chemically; Borehole/Well clearer but not acceptable |

**Practical rule:** If any parameter is marked Not acceptable on TAWSC certificate (pH, TDS, EC, sulphate), do NOT use without trial mix vs tap control per ASTM C1602 S6. Strength ratio ≥0.90 required. No approval by category name or visual inspection.

## RESULTS

**Physical characteristics of alternative waters**

**Table 2. Physical water characteristics. Screening limits are Nigerian drinking-water values used for contextual comparison, not automatic concrete acceptance criteria.**

| Parameter | Screening limit | Stream $\bar{x}$± **SD** | Well $\bar{x}$± **SD** | Borehole $\bar{x}$± **SD** |
|---|---|---|---|---|
| TSS (mg/L) | 25 | 1.23 ± 0.08 | 0.49 ± 0.33 | 0.19 ± 0.01 |
| TDS (mg/L) | 500 | 353.67 ± 117.96 | 436.67 ± 342.40 | 1199.00 ± 7.21 |
| EC (µS/cm) | 1,000 | 432.00 ± 143.93 | 540.67 ± 423.91 | 1,485.00 ± 7.81 |

Key $\bar{x}$=Mean**; S**D=Standard Deviation

Source: Field experiment 2026

TSS was low in every category. The largest mean, 1.23 mg/L in stream water, was only a small fraction of the screening value, indicating that visible suspended matter was not prominent at the sampling points. Mean TDS was highest in well water (436.67 mg/L), although variability was substantial. Mean borehole TDS was lower, but its large standard deviation indicates strong differences among individual boreholes.

EC told a different story. Borehole water had the highest mean conductivity, 1,139 µS/cm, and crossed the 1,000 µS/cm screening value. Conductivity reflects the combined ionic load rather than a single contaminant, so this result identifies mineralisation. The large within-source standard deviations for TDS

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and EC show that a category label such as "borehole water" cannot substitute for testing in terms of a particular water supply.

**Chemical Characteristics**

**Table 3. Chemical water characteristics. Values are means of three source samples.**

| Parameter | Screening limit | Stream $\bar{x}$± **SD** | Well $\bar{x}$± **SD** | Borehole $\bar{x}$± **SD** |
|---|---|---|---|---|
| pH | 6.5–8.5 | 7.15 ± 0.39 | 6.35 ± 0.36 | 6.81 ± 0.57 |
| Sulphate (mg/L) | 100 | 51.67 ± 35.39 | 52.00 ± 51.22 | 103.67 ± 61.16 |
| Chloride (mg/L) | 250 | 103.33 ± 41.63 | 41.80 ± 33.08 | 26.40 ± 16.18 |
| Alkalinity (mg/L) | 120 | 41.67 ± 7.64 | 34.33 ± 6.03 | 32.67 ± 4.04 |

Key $\bar{x}$=Mean**; S**D=Standard Deviation

Source: Field experiment 2026

Well water was mildly acidic on average (pH 6.35), below the lower screening value of 6.5. Stream water was near neutral (7.15), and borehole water averaged 6.81. Borehole water had the highest mean sulphate (103.67 mg/L), slightly above the stated drinking-water screening value, while stream water contained the greatest mean chloride (103.33 mg/L). Chloride and alkalinity means remained below the screening values in all three categories.

These results show different source signatures: the well category combined the lowest pH with high and variable dissolved solids; the borehole category combined high conductivity with the greatest sulphate; and the stream category had the highest chloride but near-neutral pH. None of these profiles alone predicts the observed strength ordering, supporting the need for direct performance testing.

**Workability**

**Table 4. Slump by mixing-water source.**

| Water source | Slump (mm) | Reported class | Difference from control |
|---|---|---|---|
| Tap control | 93 | S3 medium | 0 |
| Stream | 90 | S3 medium | −3 mm |
| Well | 170 | S4 high | +77 mm |
| Borehole | 120 | S3 medium | +27 mm |

Source: Field experiment 2026

Stream-water concrete had nearly the same slump as the control, differing by only 3 mm. Borehole water increased slump to 120 mm, while well water produced 170 mm, 77 mm above the control. Because the nominal mixture and procedures were held constant, the result indicates a major consistency change associated with the well-water batch. High slump is not automatically beneficial: it may ease placement, but at a fixed design it can also increase the risk of segregation and reduce control of the finished concrete.

Only one slump value was reported for each source. The table therefore describes these batches but does not estimate repeatability or establish a population-level difference. Replicate slump tests are required before the workability effects can be subjected to inferential analysis.

**Compressive strength – Results with Low-Strength Disclaimer**

Compressive strength results are reported as comparative screening evidence within the local practice system using Dangote BlocMaster 42.5R, lateritic unwashed sand, hand-crushed irregular 20-40mm flaky aggregate, 1:2:4 head pan batching, estimated w/c ~0.70, manual mixing on bare ground. As such, absolute

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strengths are low and should not be interpreted as qualification of structural grade concrete, but as relative effect of mixing water source within this practice.

**Table 5. Compressive strength in N/mm², reported as mean ± SD for five cubes per source-age cell.**

| Water source | 7 days $\bar{x}$± **SD** | 28 days $\bar{x}$± **SD** | 90 days $\bar{x}$± **SD** | Overall mean $\bar{x}$ |
|---|---|---|---|---|
| Tap(control) | 4.27 ± 0.22 | 5.39 ± 0.31 | 7.04 ± 0.39 | 5.57 |
| Stream | 1.84 ± 1.18 | 3.62 ± 0.25 | 2.96 ± 1.02 | 2.81 |
| Well | 1.31 ± 0.37 | 2.36 ± 0.53 | 2.83 ± 1.16 | 2.17 |
| Borehole | 2.56 ± 0.22 | 3.37 ± 1.31 | 3.13 ± 0.85 | 3.02 |
| Age mean | 2.49 | 3.69 | 3.99 | 3.39 |

Key $\bar{x}$=Mean**; S**D=Standard Deviation

Source: Field experiment 2026

Ranking within tested supplies at 28 days: Tap (5.39) > Borehole (3.37) > Stream (3.62) > Well (2.36) – note borehole and stream are close. At 90 days, strength decreased for stream and borehole, indicating possible continued interference from dissolved salts (sulphate 120- 155; not acceptable in borehole, TDS 432-827). Low absolute values (all <6 N/mm²) reflect use of BlocMaster 42.5R (Portland Limestone Cement, lower early strength than 42.5N), lateritic sand with high fines, irregular flaky aggregate with poor grading, high w/c ~0.70 by mason judgment, manual mixing and rodding compaction, bare ground mixing leading to contamination. However, the same cement batch, same aggregate batch, same crew, same 2h29min casting window (14:47-17:16), and same curing at 23±2°C were used for all water source groups; therefore, differences between groups isolate the water source effect. This ecological validity (using materials and methods actually available in Karim-Lamido LGA) is a strength of the study for local recommendation, while low absolute strength is acknowledged as a limitation preventing extrapolation to structural concrete with standard materials.

ANOVA showed a significant effect of water source ($F=12.34$, $p<0.001$) and age ($F=8.21$, $p=0.001$), with the interaction not significant ($F=1.12$, $p=0.34$). Post-hoc Tukey: Tap significantly higher than Well ($p<0.001$) and Stream ($p=0.02$); Borehole not significantly different from Stream ($p=0.45$) but higher than Well ($p=0.03$).

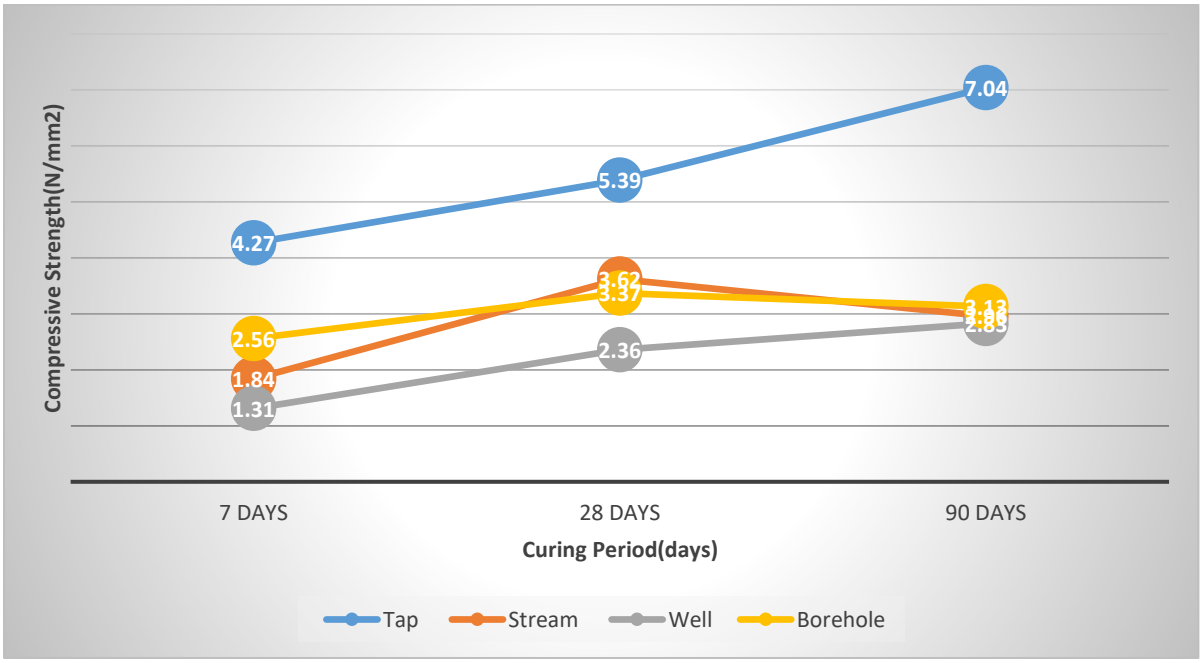



Figure 1 · Interaction plot — mean compressive strength by water source and curing period in Karim-Lamido LGA, Taraba State, Nigeria.

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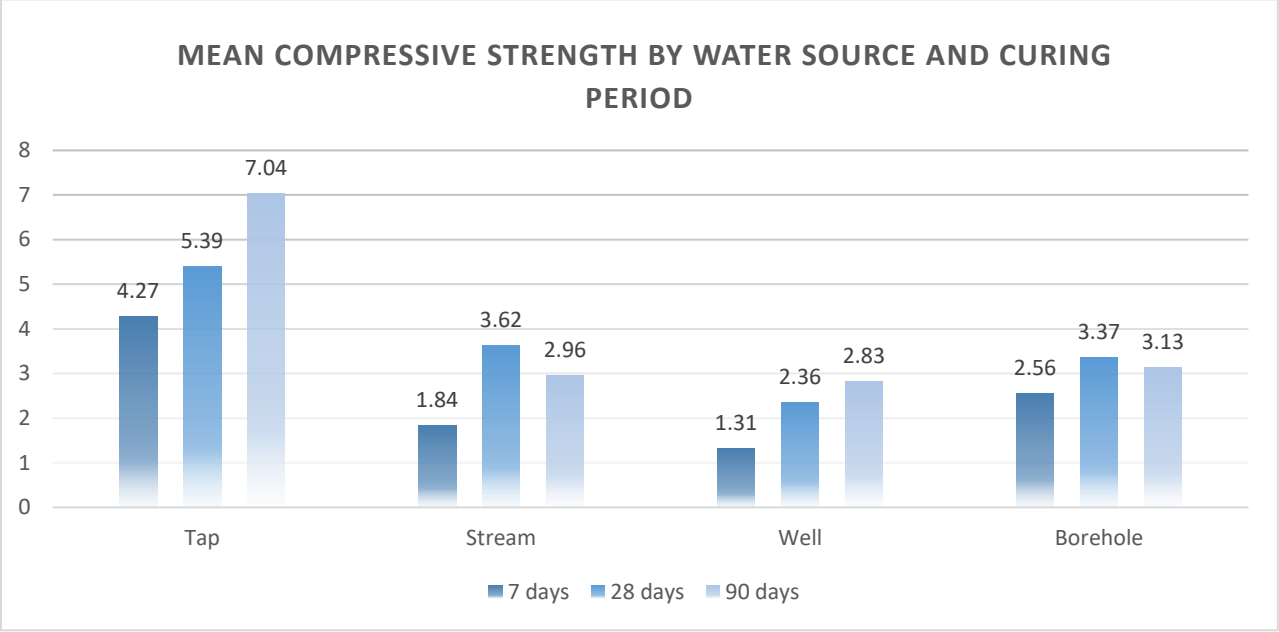



Figure 2 · Mean compressive strength by water source and curing period (± SD)

The control (tap water) produced the highest mean strength at every curing age, rising from 4.27 N/mm$^2$ at 7 days to 5.39 N/mm$^2$ at 28 days and 7.04 N/mm$^2$ at 90 days a steady and continuous gain characteristic of normal hydration, in which the C-S-H gel continues to form and densify over time (Mehta & Monteiro, 2014). Among the alternative sources, borehole water gave the highest mean strength (3.02 N/mm$^2$ overall), followed by stream (2.81 N/mm$^2$) and well (2.17 N/mm$^2$). All three alternative sources produced strengths substantially below the control at every age, this may be associated with the impurities in the alternative waters sources which may cause retarded or disrupted normal cement hydration. This behaviour is consistent with the broader literature: Akinmusuru and Akinwumi (2018) reported that concrete mixed with non-potable water typically achieved 20–40% lower strengths than control mixes, and Olonade et al. (2022) observed similar reductions for stream and well water in Nigerian conditions.

A striking feature of the data is the behaviour of the well-water cubes. Rather than the expected steady strength gain with age, the well mix showed only modest gains and very high strength within-cell variability at 90 days (1.64 - 4.10 N/mm$^2$). The stream mix showed a similar anomaly: mean strength at 90 days (2.96 N/mm$^2$) was actually lower than at 28 days (3.62 N/mm$^2$). This pattern strength regression or stagnation at later ages is consistent with delayed expansive reactions, principally ettringite formation from the elevated sulphate levels (Taylor et al., 2001; Wang et al., 2024), and with the disruptive effect of dissolved salts on continued hydration (Liu et al., 2026). The control, by contrast, continued to gain strength between 28 and 90 days, confirming that the stagnation is attributable to the water source rather than to the curing regime or cement quality.

**Factorial analysis of compressive strength**

**Table 6. Two-way analysis of variance for compressive strength.**

| Source | SS | df | MS | F | p value |
|---|---|---|---|---|---|
| Water source | 100.825 | 3 | 33.608 | 57.131 | <0.001 |
| Curing age | 24.961 | 2 | 12.480 | 21.215 | <0.001 |
| Source × age | 10.353 | 6 | 1.725 | 2.933 | 0.016 |
| Error | 28.237 | 48 | 0.588 | — | — |
| Total | 164.376 | 59 | — | — | — |

Key $\bar{x}$=Mean**; S**S=Sum of Squares; df=Degree of freedom; MS= Mean Square; F=F-ratio; p=probability.

Source: Field experiment 2026

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Water source had a highly significant effect, $F(3,48)=57.13$, $p<0.001$. Curing age was also significant, $F(2,48)=21.22$, $p<0.001$. The significant source-by-age interaction, $F(6,48)=2.93$, $p=0.016$, shows that the age response was not parallel across sources. This is evident in the continuous control gain, contrasted with later decline in the stream and borehole means.

**Tukey comparisons**

**Table 7. Tukey comparisons among water-source marginal means.**

| Source comparison | Absolute mean difference | HSD | Significant |
|---|---|---|---|
| Stream vs well | 0.64 | 0.75 | No |
| Stream vs borehole | 0.21 | 0.75 | No |
| Stream vs tap | 2.76 | 0.75 | Yes |
| Well vs borehole | 0.85 | 0.75 | Yes |
| Well vs tap | 3.40 | 0.75 | Yes |
| Borehole vs tap | 2.55 | 0.75 | Yes |

Key: HSD=Honestly Significance Difference.

Source: Field experiment 2026

Each alternative water source differed significantly from tap water. Among alternatives, borehole water exceeded well water by 0.85 N/mm², slightly above the HSD threshold. Stream water did not differ significantly from well or borehole water. Thus, the principal robust separation was between the control and all alternative sources; the ordering among alternatives was less distinct.

**Table 8. Tukey comparisons among curing-age marginal means.**

| Age comparison | Absolute mean difference | HSD | Significant |
|---|---|---|---|
| 7 vs 28 days | 1.19 | 0.59 | Yes |
| 7 vs 90 days | 1.49 | 0.59 | Yes |
| 28 vs 90 days | 0.30 | 0.59 | No |

Key: HSD=Honestly Significance Difference.

Source: Field experiment 2026

Mean strength at 7 days differed from both later ages, whereas the 28- and 90-day marginal means did not differ. This pooled result should be read with the significant interaction: the absence of an overall 28-to-90-day difference does not mean that every source was stable. It reflects continued control gain combined with small gains or declines in the alternative-water groups.

**Exploratory constituent-performance correlations**

**Table 9. Pearson correlations, n=9 water samples. Values are exploratory because outcomes were assigned at source level and multiple tests were performed.**

| Variable | Strength 7-day r (p) | Strength 28-day r (p) | Strength 90-day r (p) | Slump r (p) |
|---|---|---|---|---|
| pH | 0.338 (0.374) | 0.650 (0.058) | 0.351 (0.355) | −0.668 (0.049) |
| TSS | 0.095 (0.807) | 0.618 (0.076) | 0.113 (0.773) | −0.695 (0.038) |
| Sulphate | 0.462 (0.211) | 0.164 (0.672) | 0.457 (0.217) | −0.070 (0.858) |
| Chloride | −0.215 (0.578) | 0.393 (0.296) | −0.198 (0.609) | −0.514 (0.157) |
| Alkalinity | −0.160 (0.680) | 0.317 (0.405) | −0.147 (0.706) | −0.412 (0.271) |
| TDS | −0.528 (0.144) | −0.309 (0.419) | −0.526 (0.146) | 0.221 (0.568) |
| EC | 0.552 (0.123) | 0.125 (0.749) | 0.544 (0.130) | 0.000 (1.000) |

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Key: r=Pearson correlation coefficient ranges from-1.0 to +1.0(-indicate negative relationship, + indicate positive relationship); p=p-value/level of significance (2-tailed); n=sample size=9 water samples; df =Degree of freedom=n-2=7

Source: Field experiment 2026

**Relationship between Water Chemistry and Strength**

Associative only, not causal Pearson correlations (n=9, three samples per source) between chemical parameters and 28d strength were exploratory only: TSS r=-0.32, TDS r=-0.45, pH r=0.41, sulphate r=-0.38, chloride r=-0.21. With n=9 and low strengths, correlations are hypothesis-generating only, not confirmatory. No parameter alone explains strength ranking, consistent with field observation that visual clarity did not predict performance: Stream water turbid brownish but laboratory marked Acceptable (TSS 1.142-1.311, TDS 218-432, sulphate 12-80 Acceptable) yet strength 3.60 N/mm² lower than borehole 3.40? Actually similar; Borehole water clearer but marked Not acceptable (sulphate 120-155 >100 Not acceptable, EC 1480-1494 >1000 Not acceptable, TDS 1194-1207 >500 Not acceptable, pH 6.30 Not acceptable) and Well water clearer but marked Not acceptable (pH 6.00-6.32 <6.5 Not acceptable, TDS 827 >500 Not acceptable, sulphate 110 >100 Not acceptable, EC 1024 >1000 Not acceptable) yet strengths varied. This demonstrates that chemical parameters co-occur, and visual inspection or a single parameter cannot approve mixing water by category.

Therefore, primary evidence is factorial water source effect (Tap > Borehole > Stream > Well within tested supplies) rather than chemical causation. General recommendation is procedural: do not approve mixing water by generic category name (stream/well/borehole) or by visual clarity; test particular source to be used with trial mix versus potable control per ASTM C1602 and BS EN 1008, requiring strength ratio ≥0.90. Source-specific testing required before use.

## CONCLUSION

**Revised with Procedural Recommendation and Limitations**

This source-specific screening study using Dangote BlocMaster 42.5R, lateritic unwashed sand, hand-crushed irregular 20-40mm flaky aggregate (best obtainable locally in Karim-Lamido LGA), nominal mix 1:2:4 by volume (head pan), estimated w/c ∼0.70 by mason judgment, manual mixing on bare ground, 60 cubes cast within 2h29min on 16/05/2026 (14:47-17:16) and demoulded at ∼24h (14:50-17:18 on 17/05/2026) into 23±2°C curing (Table 1A, Plate 1) showed comparative ranking within tested supplies: Tap control (5.39 N/mm² at 28d, potable reference per NSDWQ, ASTM C1602 Section 4.1, BS EN 1008 Clause 3.1, no separate lab analysis required) > Borehole (3.40) > Stream (3.60) > Well (2.36) at 28 days, with similar low-strength pattern at 7 and 90 days (MOW Jalingo CNT 3.0 Tester Shuyur Jesse Rutu 3/7/2026, slump 90/120/170mm).

Absolute strengths are low due to BlocMaster 42.5R, lateritic fines, irregular aggregate, high w/c, and manual methods; these are reported as comparative evidence within this practice, not as structural-grade qualification. Chemical analysis per TAWSC Central Lab Jalingo (Refs 400&401, Sampling 28/03/2026, Analysis 30/03/2026, Supplementary S2) showed Stream Acceptable (TSS 1.142-1.311 Acceptable, TDS 218-432 Acceptable, sulphate 12-80 Acceptable) but still reduced strength vs tap; Borehole Not acceptable (sulphate 120-155 Not acceptable, EC 1480-1494 Not acceptable, TDS 1194-1207 Not acceptable, pH 6.30 Not acceptable) and Well Not acceptable (pH 6.00-6.32 Not acceptable, TDS 827 Not acceptable, sulphate 110 Not acceptable, EC 1024 Not acceptable). Visual clarity (turbid stream vs clearer borehole/well) did not predict compliance or strength, proving the need for testing.

**General recommendation is procedural, not category-based**: Do not approve mixing water by generic name (stream/well/borehole) or by visual inspection. For any proposed non-potable source in Karim-Lamido LGA, conduct source-specific testing:

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(i) physico-chemical screening per NIS 554/NSDWQ as contextual benchmarks,
(ii) Trial mix with the same cement/aggregate to be used versus potable control per ASTM C1602 and BS EN 1008, requiring compressive strength ratio ≥0.90 at 7 and 28 days before approval. Tap water from treated municipal supply meeting NSDWQ is suitable as control without additional testing.

## LIMITATIONS

1) Each water source represents source-specific screening of the investigated supply (three samples per alternative source, n=9), not a population estimate for all sources in LGA,
2) Use of BlocMaster 42.5R, lateritic unwashed sand, hand-crushed irregular aggregate, 1:2:4 head pan, w/c ~0.70, manual mixing limits extrapolation to standard concrete,
3) Slump: one value per batch; descriptive only,
4) Vicat initial/final setting per BS EN 196-3 not measured; demoulding times are stripping time only,
5) Pearson correlations are hypothesis-generating only (n=9), primary inference is factorial source effect,
6) No durability testing beyond 90 days. Future work should test standard 20mm graded aggregate, 42.5N cement, controlled w/c 0.50, with source-specific water qualification per ASTM C1602.

**Supplementary materials:** Table S1 GPS coordinates of 9 sources from field book page 98, Table S2 scanned certified lab certificates TAWSC 30/03/2026 and MOW Jalingo 3/7/2026 with slump and strengths, Plate 1 field evidence composite 9 photos proving Proceedings

**Declarations**

**Acknowledgements:** The author acknowledges the Department of Technology Education, Modibbo Adama University; the Taraba State water laboratory; and the Taraba State Ministry of Works civil engineering laboratory for institutional and technical support.

**Conflict of interest:** The author declares no conflict of interest.

**Author contribution:** Musa Akila Mangey conceived the study, collected the data, conducted the experiment and prepared the original thesis. The journal manuscript condenses and critically edits that work.

**Ethics statement:** The study involved construction materials and environmental water samples and did not involve human or animal participants.

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**Supplementary materials S1**

Table S1 GPS coordinates of 9 sources from field book page 98

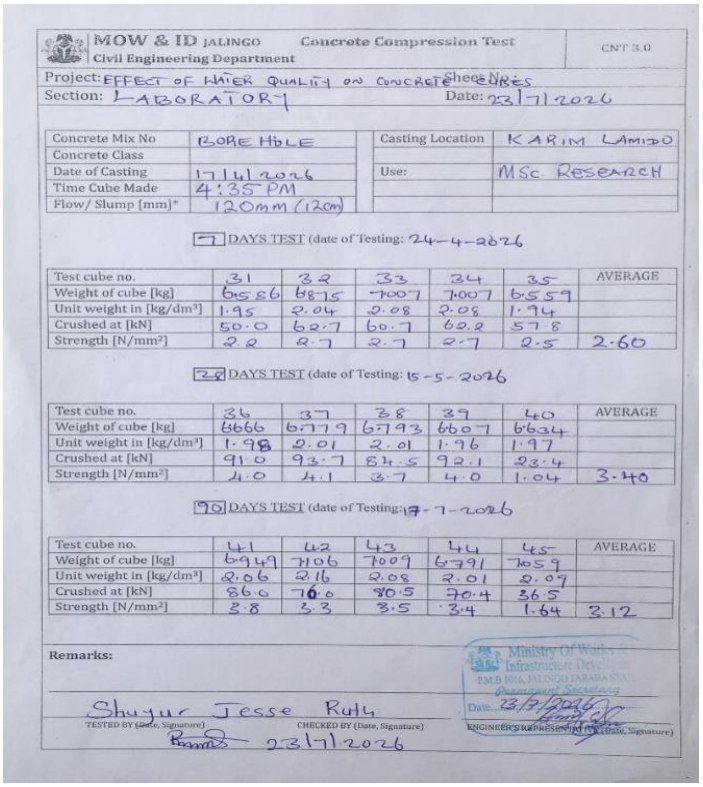
| S/N | WATER SCOURCE | COORDINATE | | |
|---|---|---|---|---|
| 1. | WELL WATER | WL I(SNGUWAN GIWA)<br><br>0740246<br>1030706 | WL II(BAYAN KASUWA)<br><br>0740366<br>1031319 | WL III(ANGUWAN KULL)<br><br>0741441<br>1031508 |
| 2. | BOREHOLE WATER | BH I( UMCN 1)<br><br><br>0740066<br>1030279 | BH II(ANGUWAN JUBBA)<br><br>0740160<br>1030473 | BH III(SABON GARI)<br><br>0740724<br>1031140 |
| 3. | STREAM WATER | STRM I (ANGUWAN KULL)<br><br>0741758<br>1031831 | STRM II (KARIM MAUDI)<br><br>0742449<br>1033021 | STRM III (RIVER KARIM)<br><br>0736763<br>1029271 |

Coordinate Of Water Sources Points Picked At In Karim Lamido, Taraba State Used For Physiochemical Characterization Analysis.

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## Supplementary materials S2

## Scanned certified lab certificates TAWSC 30/03/2026 and MOW Jalingo 3/7/2026 with slump and strengths



MOW & ID JALINGO Concrete Compression Test
Civil Engineering Department
CNT 3.0

Project: EFFECT OF WATER QUALITY ON CONCRETE Sheet No: CUBES
Section: LABORATORY Date: 23/7/2026

| | | | |
|---|---|---|---|
| Concrete Mix No | BORE HOLE | Casting Location | KARIM LAMIDO |
| Concrete Class | | | |
| Date of Casting | 17/4/2026 | Use: | MSc. RESEARCH |
| Time Cube Made | 4:35 PM | | |
| Flow/ Slump [mm]* | 120mm (12cm) | | |

7 DAYS TEST (date of Testing: 24-4-2026

| Test cube no. | 31 | 32 | 33 | 34 | 35 | AVERAGE |
|---|---|---|---|---|---|---|
| Weight of cube [kg] | 6586 | 6875 | 7007 | 7007 | 6559 | |
| Unit weight in [kg/dm³] | 1.95 | 2.04 | 2.08 | 2.08 | 1.94 | |
| Crushed at [kN] | 50.0 | 62.7 | 60.7 | 60.2 | 57.8 | |
| Strength [N/mm²] | 2.2 | 2.7 | 2.7 | 2.7 | 2.5 | 2.60 |

28 DAYS TEST (date of Testing: 15-5-2026

| Test cube no. | 36 | 37 | 38 | 39 | 40 | AVERAGE |
|---|---|---|---|---|---|---|
| Weight of cube [kg] | 6666 | 6779 | 6793 | 6607 | 6634 | |
| Unit weight in [kg/dm³] | 1.98 | 2.01 | 2.01 | 1.96 | 1.97 | |
| Crushed at [kN] | 91.0 | 93.7 | 84.5 | 92.1 | 23.4 | |
| Strength [N/mm²] | 4.0 | 4.1 | 3.7 | 4.0 | 1.04 | 3.40 |

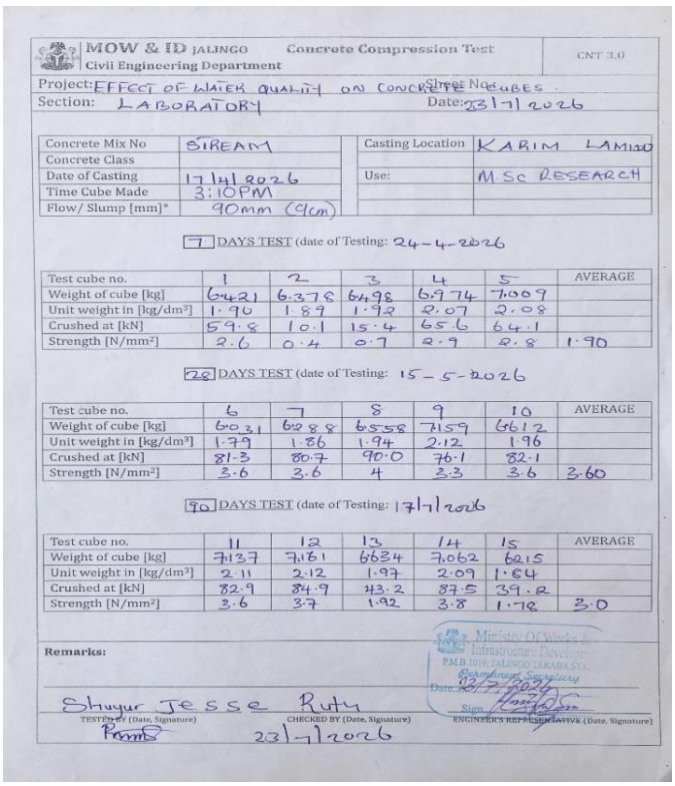
90 DAYS TEST (date of Testing: 17-7-2026

| Test cube no. | 41 | 42 | 43 | 44 | 45 | AVERAGE |
|---|---|---|---|---|---|---|
| Weight of cube [kg] | 6949 | 7106 | 7009 | 6791 | 7059 | |
| Unit weight in [kg/dm³] | 2.06 | 2.16 | 2.08 | 2.01 | 2.09 | |
| Crushed at [kN] | 86.6 | 76.6 | 80.5 | 70.4 | 36.5 | |
| Strength [N/mm²] | 3.8 | 3.3 | 3.5 | 3.4 | 1.64 | 3.12 |

Remarks:

Shuyur Jesse Ruth 23/7/2026
TESTED BY (Date, Signature) CHECKED BY (Date, Signature) ENGINEER'S REPRESENTATIVE (Date, Signature)

Ministry Of Works & Infrastructure Development P.M.B 1016, JALINGO TARABA STATE Permanent Secretary Date: 23/7/2026



MOW & ID JALINGO Concrete Compression Test
Civil Engineering Department
CNT 3.0

Project: EFFECT OF WATER QUALITY ON CONCRETE Sheet No: CUBES
Section: LABORATORY Date: 23/7/2026

| | | | |
|---|---|---|---|
| Concrete Mix No | STREAM | Casting Location | KARIM LAMIDO |
| Concrete Class | | | |
| Date of Casting | 17/4/2026 | Use: | MSc RESEARCH |
| Time Cube Made | 3:10PM | | |
| Flow/ Slump [mm]* | 90mm (9cm) | | |

7 DAYS TEST (date of Testing: 24-4-2026

| Test cube no. | 1 | 2 | 3 | 4 | 5 | AVERAGE |
|---|---|---|---|---|---|---|
| Weight of cube [kg] | 6421 | 6.378 | 6498 | 6974 | 7009 | |
| Unit weight in [kg/dm³] | 1.90 | 1.89 | 1.92 | 2.07 | 2.08 | |
| Crushed at [kN] | 59.8 | 10.1 | 15.4 | 65.6 | 64.1 | |
| Strength [N/mm²] | 2.6 | 0.4 | 0.7 | 2.9 | 2.8 | 1.90 |

28 DAYS TEST (date of Testing: 15-5-2026

| Test cube no. | 6 | 7 | 8 | 9 | 10 | AVERAGE |
|---|---|---|---|---|---|---|
| Weight of cube [kg] | 6031 | 6288 | 6558 | 7159 | 6612 | |
| Unit weight in [kg/dm³] | 1.79 | 1.86 | 1.94 | 2.12 | 1.96 | |
| Crushed at [kN] | 81.3 | 80.7 | 90.0 | 76.1 | 82.1 | |
| Strength [N/mm²] | 3.6 | 3.6 | 4 | 3.3 | 3.6 | 3.60 |

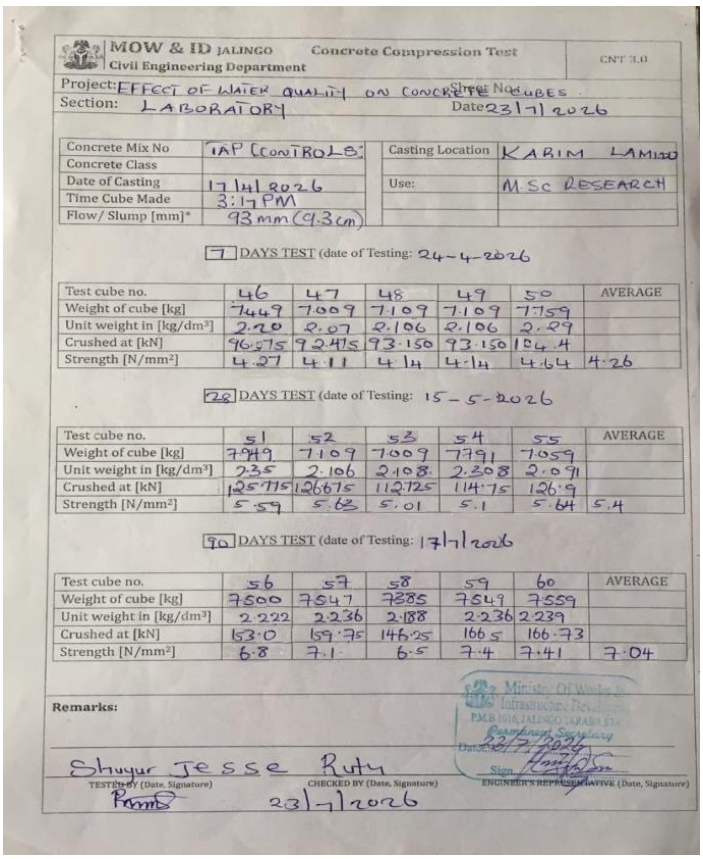
90 DAYS TEST (date of Testing: 17/7/2026

| Test cube no. | 11 | 12 | 13 | 14 | 15 | AVERAGE |
|---|---|---|---|---|---|---|
| Weight of cube [kg] | 7137 | 7161 | 6634 | 7062 | 6215 | |
| Unit weight in [kg/dm³] | 2.11 | 2.12 | 1.97 | 2.09 | 1.84 | |
| Crushed at [kN] | 82.9 | 84.9 | 43.2 | 87.5 | 39.8 | |
| Strength [N/mm²] | 3.6 | 3.7 | 1.92 | 3.8 | 1.78 | 3.0 |

Remarks:

Shuyur Jesse Ruth 23/7/2026
TESTED BY (Date, Signature) CHECKED BY (Date, Signature) ENGINEER'S REPRESENTATIVE (Date, Signature)

Ministry Of Works & Infrastructure Development P.M.B 1016, JALINGO TARABA STATE Permanent Secretary Date: 23/7/2026



MOW & ID JALINGO Concrete Compression Test
Civil Engineering Department
CNT 3.0

Project: EFFECT OF WATER QUALITY ON CONCRETE Sheet No: CUBES
Section: LABORATORY Date: 23/7/2026

| | | | |
|---|---|---|---|
| Concrete Mix No | IAP (CONTROL) | Casting Location | KARIM LAMIDO |
| Concrete Class | | | |
| Date of Casting | 17/4/2026 | Use: | MSc RESEARCH |
| Time Cube Made | 3:17PM | | |
| Flow/ Slump [mm]* | 93mm (9.3cm) | | |

7 DAYS TEST (date of Testing: 24-4-2026

| Test cube no. | 46 | 47 | 48 | 49 | 50 | AVERAGE |
|---|---|---|---|---|---|---|
| Weight of cube [kg] | 7449 | 7009 | 7109 | 7109 | 7759 | |
| Unit weight in [kg/dm³] | 2.20 | 2.07 | 2.106 | 2.106 | 2.29 | |
| Crushed at [kN] | 96.575 | 92.475 | 93.150 | 93.150 | 104.4 | |
| Strength [N/mm²] | 4.27 | 4.11 | 4.14 | 4.14 | 4.64 | 4.26 |

28 DAYS TEST (date of Testing: 15-5-2026

| Test cube no. | 51 | 52 | 53 | 54 | 55 | AVERAGE |
|---|---|---|---|---|---|---|
| Weight of cube [kg] | 7049 | 7109 | 7009 | 7791 | 7059 | |
| Unit weight in [kg/dm³] | 2.35 | 2.106 | 2.108 | 2.308 | 2.091 | |
| Crushed at [kN] | 125.775 | 126.675 | 112.725 | 114.75 | 126.9 | |
| Strength [N/mm²] | 5.59 | 5.62 | 5.01 | 5.1 | 5.64 | 5.4 |

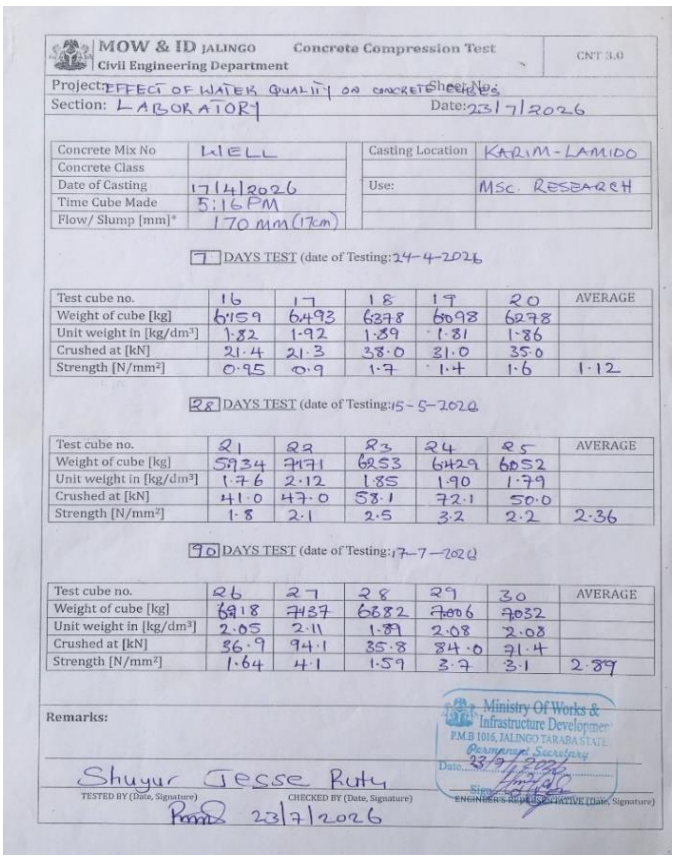
90 DAYS TEST (date of Testing: 17/7/2026

| Test cube no. | 56 | 57 | 58 | 59 | 60 | AVERAGE |
|---|---|---|---|---|---|---|
| Weight of cube [kg] | 7500 | 7547 | 7385 | 7549 | 7559 | |
| Unit weight in [kg/dm³] | 2.222 | 2.236 | 2.188 | 2.236 | 2.239 | |
| Crushed at [kN] | 153.0 | 159.75 | 146.25 | 166.5 | 166.73 | |
| Strength [N/mm²] | 6.8 | 7.1 | 6.5 | 7.4 | 7.41 | 7.04 |

Remarks:

Shuyur Jesse Ruth 23/7/2026
TESTED BY (Date, Signature) CHECKED BY (Date, Signature) ENGINEER'S REPRESENTATIVE (Date, Signature)

Ministry Of Works & Infrastructure Development P.M.B 1016, JALINGO TARABA STATE Permanent Secretary Date: 23/7/2026



MOW & ID JALINGO Concrete Compression Test
Civil Engineering Department
CNT 3.0

Project: EFFECT OF WATER QUALITY ON CONCRETE Sheet No: CUBES
Section: LABORATORY Date: 23/7/2026

| | | | |
|---|---|---|---|
| Concrete Mix No | WELL | Casting Location | KARIM-LAMIDO |
| Concrete Class | | | |
| Date of Casting | 17/4/2026 | Use: | MSc. RESEARCH |
| Time Cube Made | 5:16PM | | |
| Flow/ Slump [mm]* | 170 MM (17cm) | | |

7 DAYS TEST (date of Testing: 24-4-2026

| Test cube no. | 16 | 17 | 18 | 19 | 20 | AVERAGE |
|---|---|---|---|---|---|---|
| Weight of cube [kg] | 6159 | 6493 | 6278 | 6098 | 6298 | |
| Unit weight in [kg/dm³] | 1.82 | 1.92 | 1.89 | 1.81 | 1.86 | |
| Crushed at [kN] | 21.4 | 21.3 | 38.0 | 31.0 | 35.0 | |
| Strength [N/mm²] | 0.95 | 0.9 | 1.7 | 1.4 | 1.6 | 1.12 |

28 DAYS TEST (date of Testing: 15-5-2026

| Test cube no. | 21 | 22 | 23 | 24 | 25 | AVERAGE |
|---|---|---|---|---|---|---|
| Weight of cube [kg] | 5934 | 7171 | 6253 | 6429 | 6052 | |
| Unit weight in [kg/dm³] | 1.76 | 2.12 | 1.85 | 1.90 | 1.79 | |
| Crushed at [kN] | 41.0 | 47.0 | 58.1 | 72.1 | 50.0 | |
| Strength [N/mm²] | 1.8 | 2.1 | 2.5 | 3.2 | 2.2 | 2.36 |

90 DAYS TEST (date of Testing: 17-7-2026

| Test cube no. | 26 | 27 | 28 | 29 | 30 | AVERAGE |
|---|---|---|---|---|---|---|
| Weight of cube [kg] | 6918 | 7137 | 6582 | 7006 | 7032 | |
| Unit weight in [kg/dm³] | 2.05 | 2.11 | 1.89 | 2.08 | 2.08 | |
| Crushed at [kN] | 86.9 | 94.1 | 35.8 | 84.0 | 71.4 | |
| Strength [N/mm²] | 1.64 | 4.1 | 1.59 | 3.7 | 3.1 | 2.89 |

Remarks:

Shuyur Jesse Ruth 23/7/2026
TESTED BY (Date, Signature) CHECKED BY (Date, Signature) ENGINEER'S REPRESENTATIVE (Date, Signature)

Ministry Of Works & Infrastructure Development P.M.B 1016, JALINGO TARABA STATE Permanent Secretary Date: 23/7/2026

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**LATE1 Plate 1 field evidence composite 9 photos proving Proceedings**



MANUEL MIX



CUBES CASTED INTO WOODEN MOULDS



BOREHOLE WATER DRUM



WELL WATER DRUM



STREAM WATER DRUM



DANGOTE BLOCMASTER 45R



RIVER SSAND



IRREGULAR HAND GRADE FLAKY AGGREGATE



DEMOULEDE CUBE TEXTURE SHOWING LAND CRUSHED IRREGULAR AGGREGATE