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Evaluation of Challawa Tannery Wastewater as Mixing and Curing Water for Concrete Production

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Abstract

The increasing scarcity of freshwater resources and the growing environmental challenges associated with industrial wastewater disposal have made it necessary to explore alternative water sources for concrete production. The study was carried out to assess the suitability of tannery wastewater in Challawa Industrial Estate, Kano State, Nigeria as mixing and curing water for concrete. Concrete specimens were prepared in three different mix conditions: concrete mixed and cured with fresh water (control), concrete mixed with tannery wastewater and cured with fresh water and concrete mixed and cured with tannery wastewater. Laboratory investigations included chemical characterization of the wastewater and compressive strength testing of concrete cubes at 3, 7, and 28 days. Results showed that the wastewater possessed a pH of 9.23, chloride concentration of 5.2 mg/L, total suspended solids of 2.68 mg/L, turbidity of 0.9 NTU, and settleable solids of 34 mL/L. The compressive strengths at 28 days were 27.1 MPa, 18.7 MPa, and 26.6 MPa for the control, wastewater-freshwater, and wastewater-wastewater mixes respectively. The results indicate that although tannery wastewater may adversely affect early-age strength development, concrete mixed and cured in wastewater achieved compressive strengths comparable to conventional concrete after 28 days. The results suggest that the tested tannery wastewater has potential for use as mixing and curing water for concrete under controlled laboratory conditions, subject to compliance with applicable water-quality requirements and further durability assessment.

Keywords: *Tannery wastewater, concrete strength, industrial wastewater, sustainable construction, curing water, Challawa industrial estate.*

1.0 Introduction

Freshwater is an essential constituent in concrete production and curing. Conventional concrete manufacturing relies heavily on potable water to ensure adequate hydration and strength development. However, increasing water scarcity, rapid urbanization, industrial growth, and environmental concerns have intensified the search for alternative water sources suitable for construction activities [1], [2].

The leather tanning industry is one of the major industrial activities in northern Nigeria [3], particularly in Kano State. Challawa Industrial Estate hosts numerous tanneries that generate large volumes of wastewater containing dissolved salts, organic matter, suspended solids, and various chemical compounds [4], [5]. Improper disposal of these effluents contributes significantly to environmental degradation and water pollution [4], [5], [6], [7] [8].

Previous studies have shown that certain industrial wastewaters may be reused in concrete production without significantly affecting performance [9], [10], [11], [12], [13]. However, the chemical composition of tannery wastewater varies considerably depending on the tanning process employed. Consequently, its influence on concrete properties must be evaluated before practical implementation [9].

The utilization of industrial wastewater in concrete production offers dual benefits of conserving freshwater resources and reducing environmental pollution [1], [11], [14], [15]. This study therefore investigates the effect of Challawa tannery wastewater on the compressive strength and performance of concrete under different mixing and curing conditions. Although the use of various industrial and treated wastewaters in concrete has been investigated, limited information is available on the suitability of tannery wastewater generated from the Challawa Industrial Estate for simultaneous use as mixing and curing water. In particular, the relative effects of using tannery wastewater during mixing only versus both mixing and curing have not been adequately established under the conditions investigated.

The quality of water used in concrete production plays a critical role in determining its workability, setting time, strength, durability, and overall performance. While potable water is generally regarded as suitable for concrete mixing, recent studies have explored the use of non-potable and industrial wastewater as alternative water sources to promote sustainability, provided their chemical characteristics remain within acceptable limits. Research has shown that industrial wastewater can affect cement hydration, strength development, durability, setting characteristics, and the potential for reinforcement corrosion, with the extent of these effects depending on its chemical composition. Among such sources, tannery wastewater is notable for its high concentrations of chlorides, sulphides, organic matter, suspended solids, and chromium compounds [3], [8], [16], [17], [18], all of which may either improve or adversely affect concrete properties depending on their concentration levels and interactions with cement hydration processes.

2.0 Literature Review

2.1 Requirements for Concrete Mixing and Curing Water

Water is an essential constituent of concrete because it initiates cement hydration and provides the workability required for mixing, placing and compaction. It is equally important during curing, where the maintenance of adequate moisture permits continued hydration and development of the cementitious microstructure. Consequently, the quality of water used for mixing and curing can influence setting behaviour, strength development and the long-term performance of concrete.

Potable water has traditionally been regarded as suitable for concrete production because it generally contains low concentrations of substances capable of interfering with cement hydration. However, non-potable water may also be used where its suitability is demonstrated. ASTM C1602/C1602M-22 permits potable and non-potable sources as mixing water subject to compositional and performance requirements, including compressive strength and setting time, with optional chemical limits for chloride, sulphate, alkalis and total solids. BS EN 1008:2002 similarly specifies procedures for sampling, testing and assessing the suitability of water, including water recovered from concrete-production processes. These provisions show that alternative water should be judged by its chemical characteristics and its effect on concrete performance rather than by its source alone [19], [20].

2.2 Industrial Wastewater in Concrete Production

Increasing freshwater scarcity, industrialization and the environmental burden associated with wastewater disposal have stimulated interest in wastewater reuse in concrete. Replacing freshwater with suitably characterized wastewater can reduce demand for potable water while providing a beneficial use for effluents that would otherwise require treatment and disposal. This approach therefore supports resource conservation and circular construction practices [9], [15].

Studies have examined domestic treated wastewater, municipal wastewater and different industrial effluents as mixing or curing water. The reported effects are not uniform because wastewater composition varies widely. Asadollahfardi et al. [10] investigated concrete produced and cured using treated domestic wastewater, while Sarkar et al. [11] examined wastewater curing and its effects on strength and water absorption. Peighambarzadeh et al. [14] further showed that treated wastewater can influence fracture-related properties. Collectively, these studies indicate that wastewater can be technically feasible for concrete production, but its suitability must be established for each source and intended application.

2.3 Characteristics of Tannery Wastewater

Tannery wastewater is a particularly complex industrial effluent because leather processing involves chemical-intensive operations such as soaking, liming, deliming, pickling, tanning, dyeing and finishing. The resulting wastewater may contain dissolved and suspended solids, chlorides, sulphates, sulphides, chromium compounds and organic matter. Its composition varies with tanning technology, chemicals used, water consumption, treatment processes and dilution [3], [16], [17].

The environmental relevance of tannery effluent is well established in Nigeria. Studies have reported pollutant and heavy-metal concerns associated with tannery wastewater and have investigated treatment methods including adsorption and constructed wetlands [3], [16], [18]. Within the Challawa Industrial Estate, previous investigations have linked industrial discharges with contamination of the surrounding environment and deterioration of water quality [4], [5], [6]. These concerns provide an additional incentive to investigate technically safe reuse options for the effluent.

2.4 Previous Studies on Tannery and Related Wastewater in Concrete

Research on alternative water in concrete has expanded considerably, but much of the available evidence concerns domestic, municipal or other treated wastewaters rather than tannery effluent. Sarkar et al. [11] reported that the curing medium can influence concrete strength and water absorption. Asadollahfardi et al. [10] demonstrated the feasibility of producing and curing concrete using treated domestic wastewater, while Odeyemi et al. [12] showed that cassava wastewater affects workability and compressive strength. Micheal and El Salam (2024) also examined secondary and tertiary treated wastewater for concrete mixing and curing.

Reviews by Agwe et al. [15] and Maddikeari et al. [9] conclude that wastewater reuse can reduce freshwater consumption and may produce acceptable concrete where contaminants remain within appropriate limits. Nevertheless, the behaviour of one wastewater source cannot be transferred directly to another. Tannery wastewater has a distinctive chemical composition and therefore requires source-specific assessment, particularly when it is proposed for use during both mixing and curing.

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2.5 Effects of Wastewater on Cement Hydration

Concrete strength develops through hydration reactions between cement compounds and water, producing binding phases dominated by calcium silicate hydrate. When wastewater replaces freshwater, dissolved ions, suspended particles and organic substances may accelerate, retard or otherwise modify these reactions. The direction and magnitude of the effect depend on contaminant type, concentration and interaction with the cementitious system [9], [15].

Moderate concentrations of some dissolved salts may accelerate hydration, whereas excessive salts or organic compounds may retard hydration or alter normal hydration products. Fine suspended particles may also act as filler or nucleation sites at low concentrations, but excessive solids can increase water demand and interfere with cement-particle interactions. Because tannery wastewater may contain several chemical species simultaneously, its net effect on hydration cannot be inferred reliably from a single water-quality parameter and should therefore be established experimentally.

2.6 Effects on Early- and Later-Age Strength

Compressive strength is widely used to assess alternative mixing water because it provides an indirect measure of whether contaminants have materially affected cement hydration and microstructural development. At early ages, strength is especially sensitive to hydration kinetics. Constituents that retard hydration may reduce 3- or 7-day strength, whereas accelerating ions can increase early strength under some conditions. These competing mechanisms help explain the different trends reported for different wastewater sources [9], [15].

Later-age strength depends on continued hydration, pore refinement and the curing environment. Concrete showing delayed early strength may therefore recover substantially by 28 days if hydration continues under favourable moisture conditions. Curing is particularly important because it controls moisture availability and the chemical environment surrounding the concrete. Consequently, distinguishing between wastewater used only during mixing and wastewater used during both mixing and curing can provide useful insight into strength-development mechanisms.

2.7 Durability and Reinforcement-Corrosion Concerns

Short-term compressive strength alone is insufficient to establish the long-term suitability of wastewater concrete. Industrial wastewater may contain chlorides, sulphates and other aggressive constituents that affect durability even where 28-day strength is satisfactory. Chloride is of particular concern in reinforced concrete because sufficient chloride at the reinforcement depth can disrupt the passive protective condition of steel and initiate corrosion. This is one reason standards impose controls on chloride and other constituents in mixing water [19], [20].

Sulphate-bearing environments may also cause deleterious reactions with cement hydration products under unfavourable exposure conditions. For tannery wastewater, possible effects of sulphides, chromium compounds, organic matter and dissolved salts should also be considered. Accordingly, long-term assessment should extend beyond compressive strength to properties such as water absorption, permeability, chloride penetration, sulphate resistance, carbonation, reinforcement corrosion and microstructural development before widespread structural application is recommended.

2.8 Research Gap

The literature establishes that suitably characterized wastewater can potentially be used in concrete and that its reuse may contribute to freshwater conservation. However, much of the available research has focused on municipal, domestic, ready-mixed-concrete and treated wastewater, while comparatively limited evidence is available for tannery wastewater. Moreover, tannery effluent is highly dependent on the industrial process and location, so findings obtained elsewhere cannot automatically be generalized to Challawa Industrial Estate.

Previous investigations around Challawa have mainly addressed environmental contamination, heavy metals and water-quality impacts rather than engineering reuse of the effluent [4], [5], [6]. A further gap concerns the direct comparison of wastewater used during mixing only with its continuous use during both mixing and curing. Since hydration continues throughout curing, the curing medium may materially affect later-age performance. In addition, satisfactory compressive strength does not by itself resolve questions of long-term durability and reinforcement corrosion.

2.9 Specific Contribution of the Present Study

The present study addresses these gaps by evaluating tannery wastewater collected specifically from Challawa Industrial Estate, Kano State, Nigeria, as an alternative water source for concrete production. The experimental programme distinguishes three exposure conditions: freshwater for both mixing and curing (Mix A), tannery wastewater for mixing followed by freshwater curing (Mix B), and tannery wastewater for both mixing and curing

(Mix C). This arrangement allows the effect associated with wastewater during mixing to be compared with the combined effect of wastewater during mixing and subsequent curing.

The study further relates the physicochemical characteristics of the wastewater to compressive-strength development at 3, 7 and 28 days. Its specific contribution is therefore the location-specific assessment of Challawa tannery wastewater under contrasting mixing and curing regimes, providing preliminary evidence on whether an industrial effluent associated with environmental concerns can be beneficially reused in concrete while reducing freshwater demand.

3.0 Materials and Methods/Methodology

3.1 Materials

The constituent materials comprised Dangote 3X Ordinary Portland Cement, fine aggregate, crushed-granite coarse aggregate, freshwater, and tannery wastewater. The cement was manufactured by Dangote Cement Plc and was reported to conform to the applicable Nigerian Industrial Standard for Portland cement. Its measured specific gravity was 3.13. The fine aggregate was natural sand. Sieve analysis showed that approximately 96% passed the 2.00 mm sieve and about 1.4% passed the 0.063 mm sieve. The characteristic particle sizes were $D10 = 0.152$ mm, $D30 = 0.238$ mm and $D60 = 0.354$ mm, with $Cu = 2.33$ and $Cc = 1.05$. Its specific gravity was 2.60. The coarse aggregate was crushed granite with a measured specific gravity of 2.64. Freshwater was used as the reference mixing and curing water. The tannery wastewater was collected from Challawa Industrial Estate, Kano State, Nigeria, and was used for laboratory mixing and/or curing without any treatment in the experimental records. The measured wastewater characteristics were temperature 20–22 °C, turbidity 0.9 NTU, pH 9.23, settleable solids 34 mL/L, total suspended solids 2.68 mg/L and chloride concentration 5.2 mg/L.

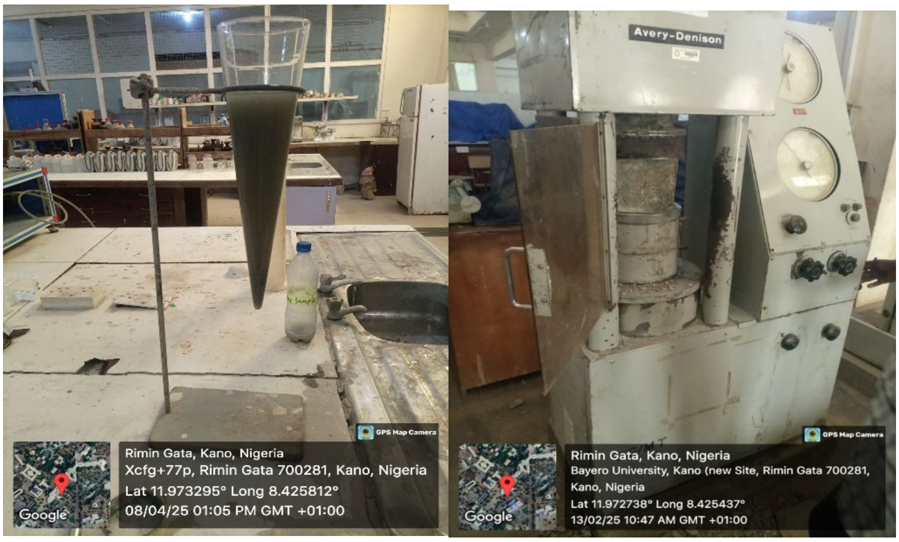

Figure 1: Experimental Set up

3.2 Experimental Program

Three concrete mixtures were prepared to evaluate the effect of tannery wastewater on concrete properties. Mix A (Control) was mixed and cured with freshwater, Mix B was mixed with tannery wastewater and cured with freshwater, while Mix C was both mixed and cured with tannery wastewater. All mixes were produced using the same materials and mix proportions.

3.3 Testing Procedures

The aggregates were tested for specific gravity and particle size distribution (sieve analysis), while the fresh concrete was assessed using the slump test. The tannery wastewater was subjected to chemical analysis to determine its physicochemical characteristics. The compressive strength of concrete cubes was determined at curing ages of 3, 7, and 28 days to evaluate strength development and compare the performance of the three mixtures.

4.0 Results and Discussion

4.1 Chemical Characteristics of Wastewater

The measured physicochemical parameters provide an initial indication of the characteristics of the Challawa tannery wastewater relevant to concrete production. The wastewater temperature ranged from 20 to 22 °C, turbidity was 0.9 NTU, pH was 9.23, total suspended solids were 2.68 mg/L, and chloride concentration was 5.2 mg/L. The mildly alkaline pH is compatible with the alkaline environment of Portland-cement systems, while the

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measured chloride and suspended-solids concentrations were low. Nevertheless, these parameters alone do not constitute a complete assessment of tannery wastewater for structural concrete because other potentially relevant constituents, including sulphates, sulphides, dissolved solids, chromium and organic matter, were not quantified in the present study. The results should therefore be interpreted as evidence that the measured parameters did not indicate an immediate water-quality constraint under the laboratory conditions investigated, rather than as comprehensive proof of compliance with all requirements of ASTM C1602/C1602M-22 or BS EN 1008:2002.

Table 1. Physicochemical Characteristics of Challawa Tannery Wastewater

Parameter	Value
Temperature	20–22°C
Turbidity	0.9 NTU
pH	9.23
Settleable Solids	34 mL/L
Total Suspended Solids	2.68 mg/L
Chloride Content	5.2 mg/L

The wastewater exhibited mildly alkaline characteristics (pH 9.23) together with measurable dissolved and suspended constituents. Such constituents may interact with cement hydration; however, the present chemical tests do not identify the mechanism of any observed strength changes. The compressive-strength results are therefore discussed in terms of plausible hydration and curing effects rather than attributing the behaviour to a specific chemical reaction without microstructural evidence.

4.2 Material Properties

4.2.1 Specific Gravity

The specific gravity tests indicate that the constituent materials possess values consistent with those commonly reported for conventional concrete production. The cement recorded a specific gravity of 3.13, which is within the typical range for Ordinary Portland Cement and confirms its suitability for concrete manufacture. The fine aggregate exhibited a specific gravity of 2.60, while the coarse aggregate recorded 2.64, both of which fall within the acceptable range for normal-weight aggregates.

Table 2. Specific Gravity of Concrete Constituent Materials

S/N	Material	Specific Gravity	Typical Range	Assessment
1	Cement	3.13	3.10–3.16	Within normal range for Ordinary Portland Cement
2	Fine Aggregate	2.60	2.55–2.70	Typical value for natural river sand
3	Coarse Aggregate	2.64	2.60–2.80	Typical value for crushed granite/gravel

4.2.2 Particle size distribution

The particle size distribution analysis indicates that the material consists predominantly of sand with a very small percentage of fines. Approximately 96% of the sample passes the 2.00 mm sieve, while only about 1.4% passes the 0.063 mm sieve, confirming that the material is essentially clean sand. The calculated characteristic particle sizes are D_{10} = 0.152 mm, D_{30} = 0.238 mm, and D_{60} = 0.354 mm, yielding a coefficient of uniformity (C_u) of 2.33 and a coefficient of curvature (C_c) of 1.05. Based on the Unified Soil Classification System (USCS), the sand is classified as SP (Poorly Graded Sand) because the fines content is less than 5%, the coefficient of curvature falls within the acceptable range of 1–3, but the coefficient of uniformity is less than the minimum value of 6 required for well-graded sands.

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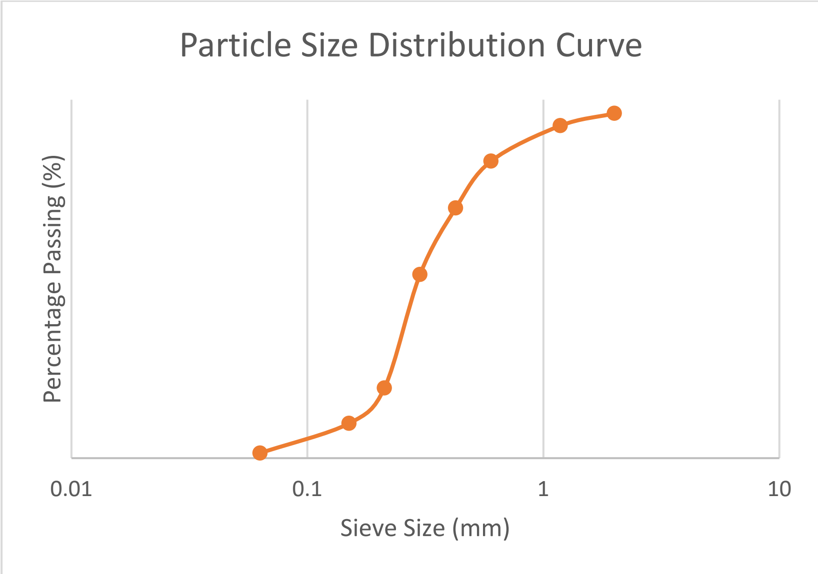

Figure 2: Particle Size Distribution Curve

4.3 Compressive Strength Development

At 28 days, Mix A achieved 27.1 MPa while Mix C achieved 26.6 MPa, a difference of approximately 1.8%, indicating comparable 28-day compressive strength under the conditions tested. Mix B, which was mixed with tannery wastewater but cured in freshwater, recorded 18.7 MPa and therefore showed a substantially lower 28-day strength. The contrast between Mixes B and C suggests that the curing environment was an important factor in the observed strength development. The observed recovery in strength at later ages may be associated with continued cement hydration and interactions between dissolved constituents in the wastewater and cement hydration products. However, the specific mechanisms responsible were not investigated in the present study and require further chemical and microstructural analysis.

Table 3. Compressive strength development of concrete under different mixing and curing conditions

Mix	**3 days (MPa)**	**7 days (MPa)**	**28 days (MPa)**
A – Freshwater/Freshwater	15.85 ± 1.56	18.37 ± 2.96	27.11 ± 3.11
B – Wastewater/Freshwater	15.41 ± 0.68	13.78 ± 0.89	18.81 ± 0.68
C – Wastewater/Wastewater	16.00 ± 0.89	11.85 ± 1.36	26.67 ± 2.04

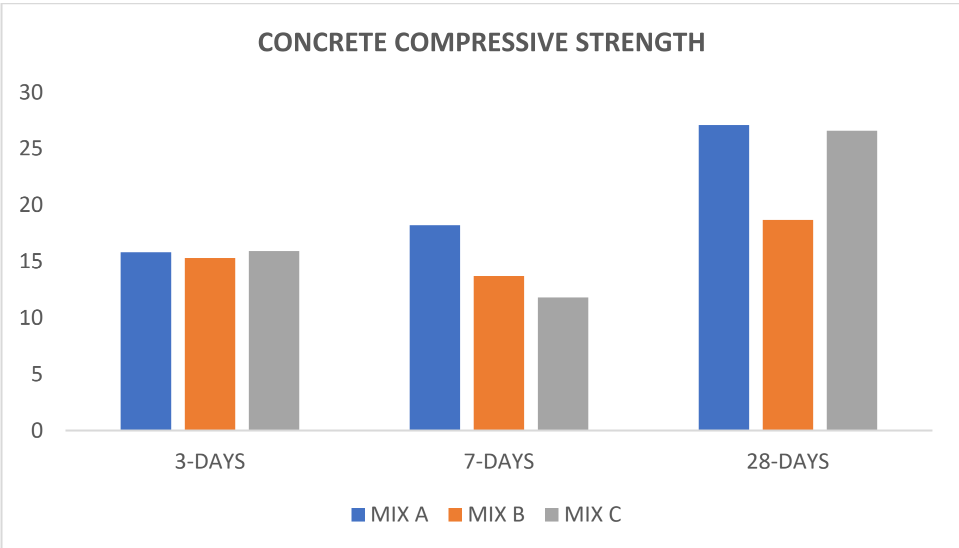

Figure 3: Compressive Strength of Concrete Under Different Conditions

Compressive strength increased with age for all mixtures, but the rate of development differed among the three curing regimes. The control mixture produced and cured with freshwater attained the highest 28-day strength of 27.1 MPa. Mix C, produced and cured with tannery wastewater, reached 26.6 MPa and was therefore close to the control at 28 days. In contrast, Mix B, produced with tannery wastewater and cured with freshwater, reached

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only 18.7 MPa. These results demonstrate that the effect of the wastewater cannot be considered independently of the curing regime. Within the scope of the present laboratory study, continuous use of the tested wastewater during both mixing and curing produced more favourable 28-day strength than its use during mixing alone. The finding is promising for beneficial reuse, but confirmation through repeat testing, broader chemical characterization and durability assessment is required before structural application can be recommended.

5.0 Conclusions

The measured physicochemical characteristics of the Challawa tannery wastewater showed a mildly alkaline pH of 9.23, low measured chloride concentration, low total suspended solids and low turbidity. These results indicate that the parameters quantified in this study did not present an immediate constraint to the laboratory concrete mixtures. However, because the investigation did not quantify all constituents potentially relevant to tannery wastewater, the findings should not be interpreted as complete verification of compliance with all chemical requirements for structural-concrete mixing water. The constituent materials otherwise exhibited specific-gravity and grading characteristics consistent with conventional concrete production.

Compressive strength increased with curing age for all mixtures. The control concrete mixed and cured with freshwater achieved 27.1 MPa at 28 days, while concrete mixed and cured with tannery wastewater achieved 26.6 MPa, representing a reduction of approximately 1.8%. Concrete mixed with tannery wastewater but cured in freshwater achieved 18.7 MPa. The substantially different performance of Mixes B and C indicates that curing conditions influenced strength development. Although continued exposure to the wastewater may have affected hydration or related physicochemical processes, the mechanism cannot be confirmed from compressive-strength testing alone.

Overall, the results provide preliminary evidence that the tested Challawa tannery wastewater may have potential as an alternative mixing and curing medium under controlled laboratory conditions, particularly where potable-water conservation is important. The evidence is strongest for 28-day compressive strength and should not yet be generalized to reinforced or durability-critical structural applications. Before practical adoption, further work should include more complete wastewater characterization, replicate strength testing, setting-time assessment, water absorption and permeability, sulphate and chloride resistance, carbonation, reinforcement-corrosion testing, and microstructural analysis. Such investigations are required to establish long-term performance, durability and compliance with applicable water-quality requirements. In addition, future studies should document the cement batch/grade, aggregate source and absorption properties, freshwater quality, and a fully reproducible wastewater sampling, storage and preservation protocol.

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