

Effect of Physicochemical Characteristics and Microbial Water Quality on Tensile Strength of *Eichhornia crassipes* Harvested from Four Rivers in Southwest Nigeria

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Abstract: This study investigated the influence of microbial water quality and physicochemical characteristics of the aquatic environment supporting the growth of water hyacinth on the mechanical properties of its fibre. Water hyacinth and water samples were collected from four rivers (Igbokoda, Makun, Epe and Badagry) in Southwest Nigeria. The load of faecal indicator bacteria in the water samples and the physicochemical characteristics of the water samples were determined using standard methods. The ASTM E 8 standard and computerized Instron testing machine were used to generate load displacement plots from which the ultimate tensile strength were determined. Pearson's correlation coefficient was used to determine the relationship between the microbial water quality, physicochemical characteristics and tensile strength of the water hyacinth fibres. The findings revealed that the load of total heterotrophic bacteria in the water samples from the rivers ranged from 3.30 to 4.36 log₁₀ cfu/100 ml and *E. coli* ranged from 3.00 to 4.18 log₁₀ cfu/100 ml. Water from Makun had the highest load of total heterotrophic bacteria counts and *E. coli*, while water from Epe had the least counts. Temperature of the water ranged from 20.7 to 20.8°C, pH 6.02 to 7.94, electrical conductivity 730 to 1272 µS/cm, total dissolved solids 360 to 648 mg/l and turbidity 0.057 to 0.095 NTU. The maximum tensile stress of the water hyacinth fibres ranged from 0.63 to 1.71 MPa, load at maximum tensile stress 31.23 to 85.23 N and tensile strain at maximum tensile stress 0.09 to 0.25 mm/mm. Pearson correlation revealed that maximum tensile stress had positive relationships with acidity ($r = 0.85$) and negative relationships with total dissolved solids and salinity ($r = -0.99$). Tensile strain had positive relationships with total dissolved solids ($r = 0.96$) and negative relationships with conductivity ($r = -0.61$). The findings of this study demonstrate that the tensile strength of *E. crassipes* fibres is not solely a function of species morphology, but a reflection of the ecological and physicochemical conditions of its aquatic environment. Integrating tensile data with water quality parameters may provide insight into how environmental stressors affect the plant's fibre microstructure and potential usability in sustainable material production.

Key word: River, tensile strength, water hyacinth, water quality

INTRODUCTION

Water hyacinth (*Eichhornia crassipes*) is an intrusive aquatic weed which grows abundantly in many water bodies like lakes, ponds, and so on. It is categorized as a floating surface aquatic weed. It is present in 70% of lakes and ponds (Karthik, *et al.*, 2024). Its growth cannot be controlled easily. Water hyacinth has many negative effects on the ecosystem. It causes depletion of dissolved oxygen in the water resources, thereby decreasing the livelihood of the river or lake. It creates a major problem during water navigation and also affects the irrigation systems (Karthik *et al.*, 2024).

Water hyacinth often obstruct water flow, contributing to boating accidents, and occasionally destroy fish and aquatic lives (Amalina *et al.*, 2022). This knowledge gap represents a significant limitation in the

development of sustainable utilization strategies for the abundant biomass resource from water hyacinth. Contaminated surface waters may pose significant risk to human health, including a higher chance of contracting waterborne illnesses such as diarrhoea, dysentery, cholera and so on. In most cases, these waters are often infested with rapid growth of water hyacinth majorly as a result of the presence of organic matter in the polluted aquatic environment (Okaba and Ezelote, 2024). Another negative impact of water hyacinth infestation of water is the reduction of sunlight penetration, which affects aquatic life and crop growth, thereby leading to financial losses for communities that depend on fishing and agriculture (Irina *et al.*, 2021).

The navigation and leisure activities that are impeded by water hyacinth mats on bodies of water also have an adverse effect on

tourism in the impacted areas (Alexander and Emmanuel, 2019). Extensive research has been carried out on the use of water hyacinth as a phytoremediation agent and studies have also demonstrated that water hyacinth fibre may be useful in making furniture and other items (Nirat, 2023). There are limited information on the influence of microbial water quality and physicochemical characteristics of the aquatic environment supporting the growth of water hyacinth on the mechanical properties of its fibre. This knowledge gap represents a significant limitation in the development of sustainable utilization strategies for the abundant biomass resource from water hyacinth. This study addresses that gap by systematically evaluating the effect of physicochemical characteristics and microbial water quality on the tensile strength of *E. crassipes* fibres collected from four rivers in Southwest Nigeria. This is to gain a better understanding of the environmental drivers of mechanical performance of *E. crassipes* fibres. This would provide baseline information on the feasibility and consistency of using locally harvested *E. crassipes* fibres as a raw material for furniture making and site selection for improved material quality.

MATERIALS AND METHODS

Description of the Study Area: This study was conducted on four major river systems located within the humid tropical zone of Southwest Nigeria, all of which support extensive growth of water hyacinth. These rivers were selected to represent diverse ecological and anthropogenic influences, ranging from rural and agricultural to urban and industrial environments. The rivers were located in Ejinrin (Lagos), Makun (Ogun), Igbokoda (Ondo) and Badagry (Lagos). Ejinrin River is located near Epe in Lagos State, it forms part of the extensive Lagos Lagoon system. It lies approximately between latitude 6°35'N and longitude 3°50'E and surrounded by low-lying floodplains and wetlands. The river receives runoff from agricultural fields, fish farms,

and small-scale settlements along its banks (Oyeleke *et al.*, 2019). The area experiences a humid tropical climate, with a mean annual rainfall of about 1,800–2,000 mm and average temperatures between 26°C and 30°C. The presence of nutrient-rich effluents from farmlands and domestic waste contributes to moderate eutrophication, creating favourable conditions for rapid water hyacinth proliferation.

Makun River flows through the Sagamu industrial corridor of Ogun State, situated around latitude 6°49'N and longitude 3°38'E. The river is influenced by discharges from food-processing, beverage, and cement industries as well as urban runoff. The physicochemical conditions of the river vary markedly between upstream and downstream segments due to differing land use patterns. Elevated levels of suspended solids, conductivity, and organic load have been reported in this area, reflecting anthropogenic stress. The surrounding vegetation comprises a mix of secondary forest and degraded wetland species, while *E. crassipes* (*gbeborun*) mats grow in the slow-moving sections of the river (Joshua, 2018).

Igbokoda River is located in Ilaje Local Government Area of Ondo State (latitude 6°21'N, longitude 4°48'E). It forms part of the coastal river network draining into the Atlantic Ocean through the Mahin lagoon complex. The river's hydrology is influenced by tidal fluctuations and seasonal freshwater inflow. Igbokoda is a major fishing and transportation hub, and its water body receives inputs from artisanal oil-processing, fishing activities, and municipal waste. The brackish-to-freshwater interface supports mixed aquatic flora, including *E. crassipes*, *Pistia stratiotes*, and *Nymphaea lotus*. Water hyacinth in this area disappears and re-appear at different seasons (Asiwaju-Bello and Owoseni, 2023).

Badagry River is a trans-boundary waterway shared between Nigeria and the Republic of Benin, lying around latitude 6°25'N and longitude 2°56'E. It flows westward into the Porto-Novo Lagoon, forming part of the

Lagos–Benin coastal drainage system. The river is characterized by high human activity, including fishing, transportation, and domestic waste disposal. The surrounding settlements discharge untreated wastewater into the river. These conditions, coupled with the river's slow flow rate, provide an ideal environment for water hyacinth infestation. The climate is typically humid tropical with rainfall exceeding 1,900 mm annually and relative humidity around 80–85% (Soyinka *et al.*, 2010).

Collection of Water Samples from the Rivers: Water samples were collected from the selected rivers supporting the growth of water hyacinth. All water samples were collected at a depth of about 20 – 30 cm below the water surface in the direction of flow using sterile, screw capped 500 ml plastic bottles. Water samples were coded with names on-site, and then transported to the laboratory in a cool box within one hour.

Collection and Preparation of Water Hyacinth Samples from the Rivers: Water hyacinth samples were harvested from the rivers with sterile hands glove into clean woven polypropylene bags. The bags were labeled appropriately. Defoliation was carried out by removing the flowers and separating the leaves from the stalk. Thereafter, the samples were cut into laboratory useable sizes and care was taken to ensure the preservation of the orientation of the relevant axes of the water hyacinth. Then, the samples were washed with distilled water and were sun-dried appropriately.

Enumeration of Bacteria in Water Samples from the Rivers: The concentrations of total heterotrophic bacteria and *E. coli* in the water samples from the rivers were determined using membrane filtration method (ISO 9308-1, ISO 7899-2). The 0.45 µm pore size membrane filter was placed on membrane setup and 100 ml of water sample was filtered. Thereafter, the membrane filters were placed on freshly prepared nutrient agar (NA) and Eosin methylene blue agar (EMB). The plates were incubated at 37°C for 24 h. Total

heterotrophic bacterial colonies on NA and colonies appearing as green metallic sheen on EMB confirming the presence of *E. coli* were counted, calculated and expressed as colony-forming units (cfu) per 100 ml of water.

Determination of Physicochemical Properties of Water Samples from the Rivers: The temperature of the water was determined on-site during sample collection using mercury-in-glass thermometer for all the four study sites. The pH, electrical conductivity, salinity, total dissolved solids, turbidity and dissolved oxygen of the water samples was determined using multi-parameter analyzer (HI98194, PH/ORP/EC/DO) in the laboratory in less than an hour of sampling. The water parameters was determined by dipping the probe of the instrument into the water samples in sterile bottle and the readings observed was recorded (APHA, 2017).

Determination of Tensile Strength of Water Hyacinth Fibres: Tensile strengths of the water hyacinth fibres were conducted as per ASTM E 8 standard. Three identical tests specimen for each section thickness per sample were tested at room temperature with a strain/ loading rate of 5 mm/mn using a computerized Instron Testing Machine (model 3369). Load displacement plots were obtained on an X – Y recorder and ultimate tensile strength, yield strength and percentage elongation values were calculated from this load displacement diagrams (Callister and Rethwisch, 2020., ASTM, 2022).

Statistical Analysis: Data obtained from the study were transformed to log₁₀ and then subjected to standard statistical analysis which include descriptive statistics and Paired sample T-test. Pearson's correlation coefficient was used to determine the relationship between the microbial water quality, physicochemical characteristics and tensile strength of the water hyacinth fibres.

RESULTS

The load of total heterotrophic bacteria in the water samples from the rivers ranged

from 3.30 to 4.36 log₁₀ cfu/100 ml. Water samples from Makun had the highest load of total heterotrophic bacteria, while water samples from Epe had the least (5.0×10^2 CFU/100 ml and 1.0×10^2 CFU/100 ml). The load of *E. coli* in the water samples from the rivers ranged from 3.00 to 4.18 log₁₀ cfu/100 ml. Similarly, water samples from Makun had the highest load of *E. coli*, while water samples from Epe had the least (Figure 1).

The temperature of the water ranged from 20.7 to 20.8°C, pH ranged from 6.02 to 7.94. The electrical conductivity ranged from 730 to 1272 µS/cm. The water samples from Epe had the highest electrical conductivity, while samples from Makun had the least. Salinity ranged from 0.06 to 0.64 mg/l. It had the highest value in water from Igbokoda and the least in water from Epe, but it was below detection limit in water samples from Makun. Water samples from Igbokoda, Epe and Makun has similar levels of alkalinity (100 mg/l), while water samples from Epe and Makun has similar levels of acidity (166.7 mg/l). The total dissolved solids ranged from 360 to 648 mg/l. The turbidity ranged from 0.057 to 0.095 NTU. The water samples from Epe had the highest turbidity, while those from Makun had the least. The dissolved oxygen ranged from 4.61 to 6.12 mg/l with water samples from Igbokoda had the highest dissolved oxygen, while samples from Badagry had the least. The biological oxygen demand ranged from 2.7 to 4.8 mg/l. Water samples from Badagry had the highest biological oxygen demand, while those from Epe had the least (Table 1).

The maximum tensile stress of the fibres ranged from 0.63 to 1.71 MPa. The fibres from Makun had the highest tensile stress, while water hyacinth from Igbokoda had the least. Similarly, the load at maximum tensile stress of the fibres ranged from 31.23 to 85.23 N. The fibres from Makun had the highest load at maximum tensile stress, while samples from Igbokoda had the least. It was observed that the tensile strain at maximum tensile stress ranged from 0.09 to 0.25 mm/mm (Figures 2 and 3). The fibres

from Badagry had the highest tensile strain at maximum tensile stress, while samples from Epe and Makun had the least. The tensile extension at maximum tensile stress of the fibres ranged from 4.40 to 12.68 mm. The fibres from Badagry had the highest tensile extension at maximum tensile stress, while those from Epe had the least. The energy at maximum tensile stress of the fibres ranged from 0.21 to 0.27 J. The fibres from Badagry had the highest energy at maximum tensile stress, while those from Igbokoda had the least. It was observed that the tensile stress at break (Standard) of the fibres ranged from 0.03 to 0.96 MPa. The fibres from Epe had the highest tensile stress at break, while those from Igbokoda had the least. Similarly, the load at break of the fibres ranged from 1.69 to 48.20 N. The fibres from Epe had the highest load at break, while those from Igbokoda had the least. The tensile extension at break (standard) of the fibres ranged from 6.33 to 14.12 mm. The fibres from Badagry had the highest tensile extension at break, while those from Epe had the least (Table 2).

Pearson correlation revealed that the load of total heterotrophic bacteria and *E. coli* in the water samples from the rivers had no significant relationship with the tensile strength of the water hyacinth fibres. The maximum tensile stress had positive relationships with alkalinity ($r = 0.50$), acidity ($r = 0.85$) and negative relationships with total dissolved solids and salinity ($r = -0.99$). Tensile strain had positive relationships with total dissolved solids ($r = 0.96$), salinity ($r = 0.94$), biological oxygen demand ($r = 0.58$) and negative relationships with water temperature ($r = -0.57$), conductivity ($r = -0.61$), alkalinity ($r = -0.69$), acidity ($r = -0.96$). The energy at maximum tensile stress had positive relationships with total dissolved solids ($r = 0.51$), salinity ($r = 0.68$), biological oxygen demand ($r = 0.98$) and negative relationships with water temperature ($r = -0.77$), conductivity ($r = -0.78$), alkalinity ($r = -0.85$), turbidity ($r = -0.51$), dissolved oxygen ($r = -0.65$) and acidity ($r = -0.83$). The

tensile stress at break had positive relationships with water temperature ($r = 0.64$), conductivity ($r = 0.68$), alkalinity ($r = 0.56$), acidity ($r = 0.90$) and negative

relationships with total dissolved solids ($r = -0.98$), salinity ($r = -0.99$) and biological oxygen demand ($r = -0.51$) (Table 3).

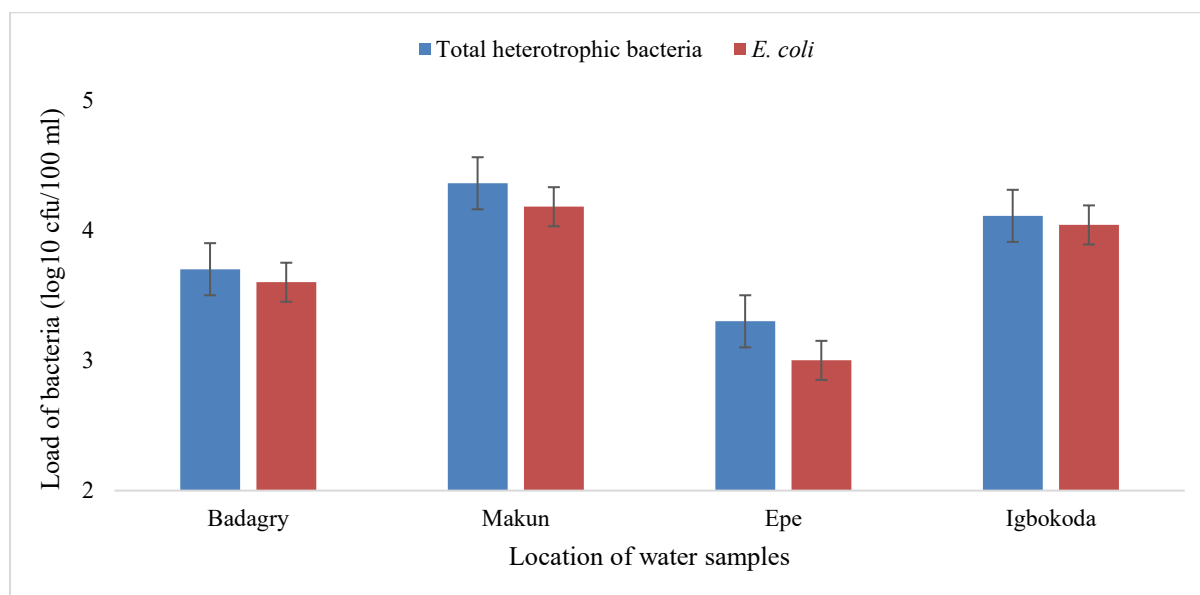


Figure 1: Concentration of Bacteria in the Water Samples from the Rivers

Table 1: Physicochemical Characteristics of Water Samples from the Rivers

Parameters	Badagry	Igbokoda	Epe	Makun
Water temperature (°C)	20.7	20.7	20.8	20.7
pH	6.99	7.28	6.02	7.94
Electrical conductivity (μS/cm)	1021	1205	1272	730
Total dissolved solids (mg/l)	510	603	648	360
Salinity (mg/l)	0.53	0.64	0.06	ND
Alkalinity (mg/l)	80	100	100	100
Acidity (mg/l)	100.0	133.3	166.7	166.7
Turbidity (NTU)	0.074	0.068	0.095	0.057
Dissolved oxygen (mg/l)	4.61	6.12	5.48	5.01
Biological oxygen demand (mg/l)	4.8	3.2	2.7	3.8

Key: ND – Non-Detect

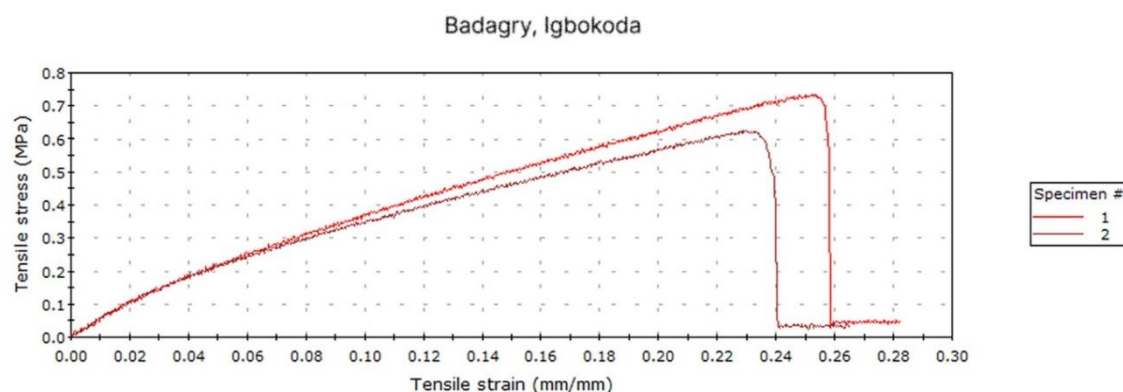


Figure 2: Tensile Strength of the Water Hyacinth Fibres from Rivers in Badagry and Igbokoda

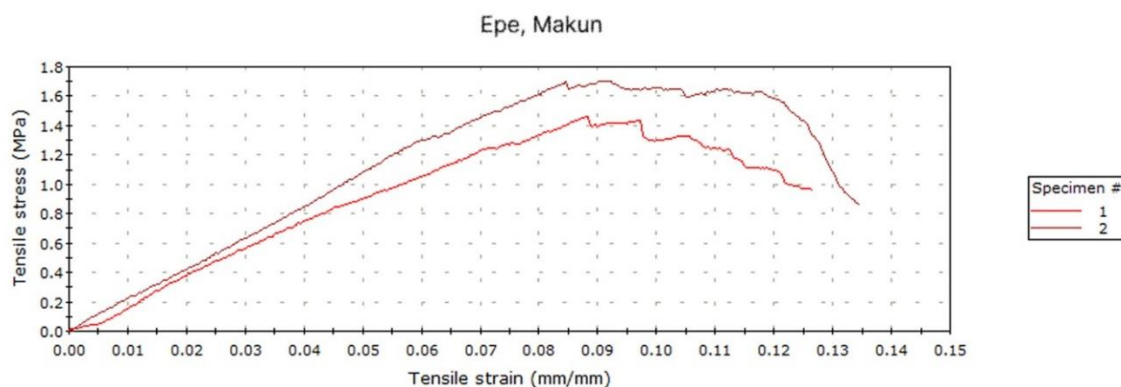


Figure 3: Tensile Strength of the Water Hyacinth Fibres from Rivers in Epe and Makun

Table 2: Tensile Strength of the Water Hyacinth Fibres from Rivers in Badagry, Igbokoda, Epe and Makun

Parameters	Badagry	Igbokoda	Epe	Makun
Maximum tensile stress (MPa)	0.73	0.63	1.46	1.71
Load at maximum tensile stress (N)	36.67	31.23	72.90	85.23
Tensile strain at maximum tensile stress (mm/mm)	0.25	0.22	0.09	0.09
Tensile extension at maximum tensile stress (mm)	12.68	11.48	4.40	4.62
Energy at maximum tensile stress (J)	0.27	0.21	0.17	0.22
Tensile stress at break (Standard) (MPa)	0.05	0.03	0.96	0.86
Load at break (N)	2.39	1.69	48.20	43.02
Tensile strain at break (Standard) (mm/mm)	0.28	0.27	0.13	0.13
Tensile extension at break (Standard) (mm)	14.12	13.23	6.33	6.72
Energy at break (Standard) (J)	0.28	0.23	0.29	0.38
Tensile stress at Yield (Zero slope) (MPa)	0.73	0.63	1.46	1.71

Table 3: Correlation Coefficient (r) between Bacterial Load, Physicochemical Characteristics of the Water from the Rivers and Tensile Strength of the Water Hyacinth Fibres

Parameters	THB	EC	Temp	pH	Con	TDS	Sal	Alk	Tur	DO	BOD	Aci
MTS	0.06	-0.10	0.41	0.07	0.45	-0.99	-0.99	0.50	0.00	-0.23	-0.32	0.85
Load at MTS	0.06	-0.10	0.41	0.06	0.45	-0.99	-0.99	0.50	0.01	-0.24	-0.32	0.85
TSa at MTS	0.04	0.20	-0.57	0.09	-0.61	0.96	0.94	-0.69	-0.16	-0.03	0.58	-0.96
TE at MTS	0.07	0.23	-0.59	0.15	-0.63	0.96	0.95	-0.67	-0.18	-0.01	0.57	-0.95
Energy at MTS	0.31	0.41	-0.77	0.47	-0.78	0.51	0.68	-0.85	-0.51	-0.65	0.98	-0.83
TSe at break	-0.17	-0.33	0.64	-0.19	0.68	-0.98	-0.99	0.56	0.26	-0.10	-0.51	0.90
Load at break	-0.17	-0.33	0.64	-0.20	0.68	-0.98	-0.99	0.57	0.26	-0.10	-0.51	0.90
TSa at break	0.08	0.23	-0.58	0.11	-0.61	0.98	0.97	-0.62	-0.17	0.06	0.51	-0.92
TE at break	0.10	0.25	-0.61	0.14	-0.64	0.97	0.96	-0.65	-0.20	0.01	0.56	-0.94
Energy at break	0.36	0.24	-0.05	0.45	-0.01	-0.82	-0.76	0.16	-0.39	-0.56	0.17	0.53
TSe at Yield	0.06	-0.10	0.41	0.07	0.45	-0.99	-0.99	0.50	0.00	-0.23	-0.32	0.85

Keys: MTS - Maximum tensile stress; TSe - Tensile stress; TSa - Tensile strain TE - Tensile extension; THB – Total heterotrophic bacteria; EC – *E. coli*; Temp – Temperature; Con – Conductivity; TDS – Total dissolved solids; Sal – Salinity; Alk – Alkalinity; Tur – Turbidity; DO – Dissolved oxygen; BOD – Biological oxygen demand; Aci – Acidity; Values in bold indicate significant correlation

DISCUSSION

This study investigated the effect of physiochemical characteristics and microbial water quality on the tensile strength of *E. crassipes* fibres harvested from rivers in Epe (Lagos), Makun (Ogun), Igbokoda (Ondo) and Badagry (Lagos). The rate of faecal

pollution of surface waters is categorized into five different classes based on the concentration of *E. coli* as: Class 1 – little pollution ($\leq 2 \log_{10}$ cfu/100 ml), Class 2 – moderately polluted ($> 2 - 3 \log_{10}$ cfu/100 ml), Class 3 – critically polluted ($> 3 - 4 \log_{10}$ cfu/100 ml), Class 4 – strongly

polluted ($> 4 - 5 \log_{10}$ cfu/100 ml) and Class 5 – excessively polluted ($> 5 \log_{10}$ cfu/100 ml) (Kavka *et al.*, 2006; Olalemi and Akinwumi, 2022). Based on these categories, water from River Epe was moderately polluted, while water from River Badagry was critically polluted, and water from Rivers Makun and Igbokoda were strongly polluted. The loads of heterotrophic bacteria and *E. coli* in water from these rivers were high exceeding the threshold level of $3 \log_{10}$ cfu/100 ml for good recreational water. This suggests pollution sources from both point and non-point sources that include indiscriminate disposal of sewage and channeling of sewerage, industrial and agricultural wastes into the rivers. Tropical surface waters generally maintain warm temperatures (26–32°C) that may accelerate bacterial metabolism and reproduction. This may also be responsible for the high loads of bacteria in water from the rivers. Several regional studies support the patterns observed in this research. According to Adesemoye *et al.* (2006), in Ogun and Yewa Rivers (Ogun State), total coliform counts exceeded 10^3 cfu/100 ml in communities near abattoirs and open defecation sites as a result of direct sewage discharge and livestock washing. Similarly, Adefemi *et al.* (2018) reported *E. coli* densities ranging from 1.2×10^2 to 9.0×10^2 cfu/100 ml, depending on proximity to human settlements in Badagry Creek (Lagos). Olalekan *et al.* (2020) reported high microbial loads linked to fish processing and domestic waste along riverbanks in Igbokoda, Ondo State. These findings suggest that human and agricultural activities remain dominant sources of microbial pollution in most surface waters across Southwest Nigeria is reflected in the higher strain values recorded at break, indicating a tendency toward elongation before rupture rather than early fracture. The water hyacinth fibres exhibited moderate tensile strength, characteristic of aquatic plant materials with high moisture and lignocellulosic composition. The mean maximum tensile stress was 0.68 ± 0.08

MPa, with no variation in span or diameter across replicates. The corresponding load at maximum stress averaged 33.95 N, while the tensile strain at maximum stress was 0.24 ± 0.02 mm/mm, indicating good flexibility before rupture. At the point of failure, the mean tensile stress at break was 0.041 ± 0.010 MPa, with a tensile extension of approximately 12.08 mm. The energy absorbed at maximum stress averaged 0.24 J, suggesting low energy storage capacity typical of semi-aquatic fibres. A notable increase in strain values at break compared to maximum stress (0.28 mm/mm vs. 0.24 mm/mm) indicates that the fibres underwent plastic deformation before complete rupture. This behavior suggests a ductile failure mode rather than brittle fracture, which aligns with previously reported mechanical behaviour of *E. crassipes* and other aquatic biomass fibres used in composite or adsorption application (Faruk *et al.*, 2012). The coefficient of variation for tensile parameters ranged from 8–11%, reflecting moderate reproducibility for natural fibre samples. The 95% confidence intervals, although wide due to the limited sample size, confirm consistency between specimens in terms of both stress and strain responses.

It is important to note that among the four sites, River Makun appeared to have the best water quality, with low conductivity, low solids, and balanced oxygen levels. Water from River Epe was slightly acidic but had less saline, while water from Rivers Badagry and Igbokoda exhibited clear signs of high salinity and chemical contamination. The combined data suggest that while physical clarity was maintained, the chemical and biological quality was compromised, particularly in areas closer to marine influence. The physicochemical characteristics of the water bodies likely contributed significantly to the observed mechanical variations of the water hyacinth fibres. Elevated concentrations of dissolved solids, organic matter, and heavy metals, often present in rivers receiving domestic or industrial effluents, may alter cellulose

crystallinity and lignin deposition during plant growth (Faruk *et al.*, 2012; Kabir *et al.*, 2018; Shahid and Ansari, 2018). Fibres from such environments tend to show reduced tensile strength due to partial degradation or uneven microfibril alignment within the cell wall matrix. In this study, the water hyacinth fibres had tensile strain or strength that demonstrated positive relationships with total dissolved solids, salinity, and biological oxygen demand. The maximum tensile stress also exhibited positive relationships with alkalinity and acidity. Conversely, sites with moderate conductivity may yield fibres with improved structural integrity and stress-bearing capacity. This may be responsible for the positive relationship observed between the tensile stress at break and conductivity in this study (Faruk *et al.*, 2012). Makun, the most mechanically stable, had the lowest EC, TDS, and COD, meaning the cleanest and least saline water. This likely allowed the plants to develop denser parenchyma and stronger fibre walls, reflected in their higher flexural stress and energy absorption (≈ 0.19 MPa, ≈ 4.0 J) (Faruk *et al.*, 2012). Epe's water was acidic (pH 6.02) and moderately polluted. Acidity tends to soften and partially hydrolyze cellulose fibres, making them less stiff and more prone to bending failure. That aligns with its lower mechanical performance lower stress (~ 0.10 MPa) and lower energy (~ 1.7 J). The stems may have been flexible but fragile. Badagry, saline and weak with very high TDS (5100 mg/l) and high COD (3120 mg/l), suggesting heavy salt and chemical presence. Salinity can cause osmotic stress, reducing cell wall thickness and fibre strength. Although, its water looked clear, the stems were weaker and less elastic, with stress around 0.12 MPa and energy near 2.0 J showing mechanical fatigue. Igbokoda's water was highly saline (0.64) and chemically loaded (COD 3200 mg/l), yet DO was high (6.12 mg/l), which may have slightly offset the damage. The plants showed moderate strength (0.14 MPa) and relatively good energy (3.3 J), possibly due to partial adaptation to brackish

conditions (Faruk *et al.*, 2012). In essence, Igbokoda plants endured stress, but developed resilience.

The tensile behavior of *Eichhornia crassipes* fibres observed in this study reflects the influence of both intrinsic plant structure and the environmental conditions of the harvesting sites. The relatively low tensile strength values (0.62–0.73 MPa) are consistent with fibres from aquatic macrophytes that possess thin cell walls and high water retention capacity (Faruk *et al.*, 2012). These anatomical traits, while beneficial for buoyancy and nutrient transport, generally reduce mechanical rigidity compared to terrestrial bast fibres such as jute or kenaf.

The findings of this study demonstrated that the tensile strength of *E. crassipes* fibres is not solely a function of species morphology, but a reflection of the ecological and physicochemical conditions of its aquatic environment. Integrating tensile data with water quality parameters may provide insight into how environmental stressors affect the plant's fibre microstructure and potential usability in sustainable material production.

CONCLUSION

The microbial and observed physicochemical profiles of Badagry, Makun, Epe, and Igbokoda demonstrated moderate-to-high levels of organic pollution typical of poorly protected surface waters in rapidly urbanizing coastal regions. The pattern of Makun > Igbokoda > Badagry > Epe revealed a gradient of contamination linked to human population density and waste discharge. The findings highlight the need for integrated water-quality monitoring, community sanitation initiatives, and enforcement of environmental regulations. Routine surveillance combining microbial, chemical, and physical analyses would help safeguard public health and support sustainable water resource management in South Western Nigeria. The findings demonstrated that tensile strength in *E. crassipes* is not solely a

function of species morphology, but a reflection of the ecological and biochemical conditions of its aquatic environment. Integrating tensile data with water quality parameters such as pH, conductivity, dissolved oxygen, and microbial count can therefore provide insight into how environmental stressors affect the plant's fibre microstructure and potential usability in sustainable material production. The relatively high strain and low energy absorption observed in this study suggests that *E. crassipes* fibres behave as semi-

ductile biomaterials—capable of stretching appreciably under load, but unable to store or transfer substantial mechanical energy. From an application standpoint, this property can be advantageous for low-load composite materials, adsorbent mats, or biodegradable reinforcements, where flexibility and water compatibility are desirable traits. However, for structural applications requiring high modulus or dimensional stability, further chemical modification or hybridization with stronger natural fibres would be necessary.

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