WATER HYACINTH FIBRE REINFORCED COMPOSITE FOR LIGHT WEIGHT SHIP INTERIORS

A SUSTAINABLE MARINE ENGINEERING APPROACH

BY

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CERTIFICATION

I hereby certify that this project work **INVESTIGATION OF THE POTENTIALS OF WATER HYACINTH FIBRE REINFORCED COMPOSITE FOR THE PRODUCTION OF LIGHT WEIGHT SHIP INTERIORS** was carried out by

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DEDICATION

This project is dedicated to God Almighty, whose divine guidance, wisdom, and strength have seen us through this work. We also dedicate it to our beloved family for their constant love, prayers, encouragement, and support throughout this journey.

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ABSTRACT

This study investigates the potential of Water Hyacinth Fiber Reinforced Composites (WHFRC) as lightweight materials for ship interior applications. Water hyacinth, an abundant aquatic weed found in Nigerian inland waterways, was considered due to its low cost, availability, and environmental advantages. The research focused on extracting fiber from water hyacinth petioles through water retting, followed by fabrication of composite samples using epoxy resin and a cashew-nut shell liquid-based hardener.

Materials used included water hyacinth fibers as reinforcement. Equipment utilized comprised an oven dryer for heat treatment, analytical weighing balance for mass measurements, universal testing machine for tensile and flexural strength analysis, and water absorption apparatus for evaluating hydrophilicity. The harvested water hyacinth was dried at ambient temperature to remove excess water for 14days, sample representative was taken to the for further heating using heat furnace. It was weighed before being heated at 100°c and then brought out weighing to determine moisture loss. This was done at 200°c, 300°c and 600°c(this is where carbonization takes place). At 300°c the specimen was taken for water absorption test for 24hours

Tests carried out included tensile, thermal stability, water absorption, and flexural strength. Results showed that water hyacinth fiber composites exhibited low tensile strength, poor thermal stability, and extremely highwater absorption (above 500%), leading to failure in flexural strength tests. These results indicate that water hyacinth fibers are unsuitable for direct use in marine composite applications, especially for ship interior panels exposed to moisture and temperature variations. The study concludes that although WHFRCs are environmentally friendly, their high hydrophilicity and weak bonding characteristics limit their application in the marine sector unless surface treatment or hybridization with stronger fibers is applied.

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND TO THE STUDY

The marine industry is undergoing a significant transformation, driven by an urgent need for sustainable practices to mitigate its environmental footprint. As global regulations tighten and the cost of fossil fuels rises, stakeholders are increasingly focused on reducing vessel weight and enhancing energy efficiency through sustainable design and materials selection. Traditionally, materials like fiberglass and various synthetic polymers have dominated ship interior construction. While durable, these materials pose significant environmental challenges. Their production is energy-intensive, they are derived from non-renewable petroleum resources, and their eventual disposal contributes to landfill waste and micro-plastic pollution.

The non-biodegradable nature of these materials and their considerable weight directly translate to higher fuel consumption and operational costs, contradicting the industry's push toward a greener future (Pickering et al., 2016). In response, there has been a global push to explore innovative, eco-friendly alternatives. Natural fiber composites have emerged as a promising solution, offering a compelling blend of sustainability, performance, and cost-effectiveness. These composites utilize fibers from renewable sources, resulting in a lower carbon footprint and reduced environmental impact throughout their lifecycle. The need for improved properties of engineering materials has necessitated researches on exploring various materials combination to harness their individual properties as a joint contribution to the properties of the parent composite. Modern materials ranging from smart materials, sandwich materials and bio-composites are now extensively explored to replace conventional materials, human tissues and skeletal parts. However, to ensure their efficient performance, reliability and durability it has become pertinent to systematically have a mix of two or more of the primary composite materials which can be controlled. The ability to control such materials mix will enable the control, variation and achievement of desired properties of the parent composite material. Composite materials combine the advantages of the varying material properties of two or more materials with no tendency of dissolving or blending into each other. (Ngo, 2020). These properties may include strength, corrosion resistance, thermal conductivity, weight etc. Material like wood by nature can be described as a composite considering its materials combination of cellulose fibers and lignin both contributing low density and strength properties respectively to the wood. In similar form bone can be thought of as a composite material; something made out of two materials with different properties, which when brought together produce a new material with new properties. use to test the strength properties of a composite material. The core material is normally low strength material, but its higher thickness provides the sandwich composite with high bending stiffness with overall low density. Composites can be found everywhere in our lives. Some examples of engineered and natural composite materials are:

i. Concrete
ii. Plywood
iii. Fiberglass
iv. Bone
v. Teeth
vi. Wood
vii. Shells

Considering the marine environment which is the focus of this project, one particularly compelling and underexploited resource which can be studied for its materials selection for potential use in marine vessel interior accessories making is the water hyacinth (Eichhornia crassipes). This invasive aquatic plant, which proliferates in tropical waterways worldwide, is often considered a nuisance due to its rapid growth, which chokes waterways and disrupts local ecosystems. However, its fibrous structure, rich in cellulose, makes it a probable material of mechanical properties good enough to form composites with other materials with reinforcement properties for ship interior making. Water hyacinth shown in Figure 1.1 in combination with other materials such as polymer or metal dust may possibly be a useful material with good mechanical properties which may also depend on the nature of use and production.

Figure 1.1 Water Hyacinth grown in water

By harnessing abundant and low-cost resources like the water hyacinth, researchers have developed composites with remarkable properties. When water hyacinth fibers are properly treated, for instance, with a sodium hydroxide or cashew water solution—and combined with an epoxy matrix, the resulting material exhibits impressive mechanical properties. Studies have shown these composites can achieve tensile strengths of approximately 150–200 MPa and densities ranging from 1.2 to 1.4 g/cm^3. These characteristics make them a viable lightweight alternative to conventional materials, particularly for non-structural interior components in marine vessels (Sanjay et al., 2018). The potential applications are vast, from tugboats, where lightweight interiors enhance maneuverability and fuel efficiency, to ferries, cruise ships, and cargo vessels. The utilization of water hyacinth thus offers a dual benefit: it addresses a critical ecological problem while simultaneously advancing sustainable design and material innovation within the marine sector.

1.2 STATEMENT OF THE PROBLEM

The marine industry's ongoing reliance on heavy, non-biodegradable materials for ship interiors remains a significant barrier to achieving ambitious sustainability targets set forth by organizations like the International Maritime Organization (IMO). This issue is particularly acute in vessels like tugboats, where the weight of interior fittings directly impacts fuel consumption and operational efficiency. While alternatives such as jute and hemp fibers have been explored, their widespread adoption is limited by their direct competition with agricultural resources for land use, which can create a different set of sustainability challenges. To advance sustainable ship design in term of lightweight materials usage, fuel economy and environmental protection, material resource like the water hyacinth, an abundant and often-unwanted resource, is perceived to presents a unique and underutilized opportunity. There have been critical challenges hindering the widespread application of water hycinth in marine environments. The primary obstacles include the fibers' inherent tendency for moisture absorption, which can lead to material degradation, and their inadequate fire resistance, which is a major safety concern in maritime applications. Furthermore, the fabrication process requires careful optimization to ensure a strong and stable bond between the natural fibers and the polymer matrix, such as epoxy. Without proper treatment and fabrication, the performance of the final composite can be compromised, failing to meet the stringent performance criteria for tensile strength, fire resistance, and durability required for marine applications. However, there is a clear and pressing need to develop and rigorously test water hyacinth fiber-reinforced composites, employing scientific treatment methods test their suitability for use and performance for marine vessels interiors and broader marine applications.

1.3 AIM AND OBJECTIVES OF THE RESEARCH

The aim of the project is to investigate the suitability of use of water hyacinth composite in the production of marine vessel interior accessories. The ultimate goal is to create a lightweight, sustainable, and high-performance material suitable for tugboat interiors, with the potential for wider adoption across various marine vessels.

The objectives of the project are as follows:

i. Source, extract and study the internal structure of Water Hyacinth fiber
ii. Carry out Thermal and Water absorption test: of water hyacinth
iii. Prepare a water hyacinth and saw dust composite

iv. Conduct performance test on the produced composite to determine its key performance indicators which include tensile strength, fire resistance, thermal conductivity, and water resistance properties.

v. To analyze the test results to evaluate the practical suitability of these composites for non-structural tugboat interior components, such as panels, partitions, and furniture. This will also include an assessment of their potential applications in other vessels, including ferries and cargo ships.

vi. Production and Compliance Strategy: To identify and propose solutions for the major production challenges associated with large-scale manufacturing of these composites, while also outlining a clear strategy for ensuring compliance with international marine safety standards and regulations.

1.4 SCOPE OF THE RESEARCH

This research project is strategically focused on the testing of water hyacinth as a probable material for marine accessories on marine vessel. The research will also dwell on the development and evaluation of water hyacinth fiber-reinforced composites. The final material is specifically targeted for non-structural, lightweight interior applications in tugboats, including wall panels, partitions, and furniture. the study will also consider the broader potential for these composites in other vessels, such as ferries and cargo ships, which also benefit from weight reduction and sustainability. The scope of testing will be basic as a precept for a comprehensive investigation designed to validate the material's suitability for the demanding marine environment. This includes assessing its mechanical properties (tensile strength), safety characteristics (fire and water resistance to meet stringent marine standards), and comfort-enhancing attributes (thermal conductivity and acoustic insulation). It is important to note that this study deliberately excludes structural or submerged marine applications. This is due to the inherent moderate strength of natural fiber composites and the potential risks of biodegradation in constantly wet or submerged conditions. The project will address the theoretical scalability of production but will not include the full-scale industrial manufacturing process itself.

1.5 SIGNIFICANCE OF THE PROJECT

This research holds significant importance for several key stakeholders and for the marine industry as a whole. First and foremost, it champions sustainable marine engineering by transforming an invasive, problematic weed into a valuable, eco-friendly resource. This innovative approach reduces the reliance on traditional, environmentally harmful materials while simultaneously supporting ecological restoration efforts in regions afflicted by water hyacinth infestations.

For tugboats, which operate in challenging and often demanding conditions, the development of lightweight water hyacinth composites offers a direct pathway to enhanced fuel efficiency and maneuverability. The reduction in dead weight translates to lower operational costs and a smaller carbon footprint, which is a critical advantage in today's environmentally conscious market.

Furthermore, the project’s exploration of eco-friendly treatments, such as cashew water, highlights a commitment to minimizing the environmental impact throughout the material's entire lifecycle. The findings of this research are expected to contribute valuable data to the growing body of knowledge on marine-grade bio-composites. By aligning with the IMO's decarbonization goals and promoting the adoption of sustainable materials, this project has the potential to inspire broader innovation and change within the global marine industry. It not only addresses a technical challenge but also presents a viable economic and ecological solution.

CHAPTER TWO

LITERATURE REVIEW

2.1 Understanding Deforestation and Its Severe Impacts in Nigeria

What Deforestation Means and Its Extent

Deforestation refers to the complete and lasting removal of forest areas—defined as land with at least 10% tree canopy, covering a minimum of 0.5 hectares, and trees reaching 5 meters or more—replaced by farms, cities, or bare ground. In Nigeria, this is a fast-moving, permanent loss of natural ecosystems. From 2020 to 2025, Nigeria lost an average of 410,000 hectares of forest each year, equivalent to an area bigger than Lagos State disappearing annually. The Cross River rainforest, once a world-renowned ecological hotspot, has been reduced by more than 70% since 1990. In the Guinea Savanna zone, 90% of forest decline comes from unsustainable charcoal making and fuelwood gathering.

Key causes include:

- Illegal timber harvesting
- Expansion of farms for crops like yam, cassava, and cocoa
- Construction of roads, pipelines, and dams

- Rapid urban growth around cities such as Lagos, Abuja, and Port Harcourt

2.1.2 Environmental Systems in Collapse

2.1.3 Turning Carbon Storage into Emissions

Nigeria's forests hold more than 2.5 billion tons of carbon. Clearing just one hectare releases 150 to 250 tons of CO equivalent (CO e). Today, deforestation contributes nearly 40% of Nigeria's total greenhouse gas emissions, exceeding the combined output from electricity, factories, and vehicles. In the Niger Delta, the destruction of mangrove soils adds another 1.2 million tons of CO e to the atmosphere every year.

Threat to Wildlife and Ecosystem Services

Remaining forest patches like Gashaka-Gumti, Okomu, and Oban Hills are critical habitats for endangered species including the Cross River gorilla, Nigeria-Cameroon chimpanzee, and forest elephant. Over 120 plant and animal species are now at risk of disappearing from Nigeria due to habitat loss. Even pollinators essential for cocoa and oil palm farming are declining as forest islands shrink.

Disruption of Water Cycles

Trees on the Jos Plateau and Obudu highlands once stabilized rainfall and river flow for the Niger and Benue rivers. Now, surface runoff has risen 300%, triggering catastrophic floods in places like Lokoja and Makurdi. At the same time, dry-season water levels have fallen 60%.

In the southwest, Ogun and Osun river basins—where forest cover is below 10%—experience extreme drought followed by sudden flooding.

Human and Social Consequences

Forest loss directly affects millions:

• Over 70 million Nigerians depend on forests for food, medicine, and cooking fuel.

• Soil erosion now damages 35 million hectares of farmland, or 80% of Nigeria's cultivable land.

• Flooding displaces more than 2 million people yearly, especially in the Niger Delta and northern river plains.

• Fish production in Kainji Lake has dropped 65% due to silt buildup and water hyacinth spread.

• Indigenous cultures of the Ijaw, Efik, Tiv, and Yoruba Ifon are fading as sacred forest groves are cleared.

II. How Marine Infrastructure Fuels Inland Forest Loss

"A new port in the Delta opens a highway into the heart of Cross River's forests." Nigeria's vital coastal projects—Lekki Deep Sea Port, Bonny LNG terminals, Onne Oil & Gas Zone, and dredged shipping channels—support trade and energy. Yet they indirectly accelerate forest destruction far inland.

Immediate Damage: Mangrove Destruction

The Role of Mangroves

Nigeria once had Africa's largest mangrove ecosystem, covering over 1 million hectares. These forests stored up to 1,000 tons of carbon per hectare, protected coastlines from storms, and supported 90% of nearshore fish species.

The Losses

Since 1980, more than 600,000 hectares of mangroves have vanished:

• Port Harcourt and Warri ports: Over 80,000 hectares cleared for docks and storage.

• Oil spills and dredging: 150,000 hectares severely damaged.

• Lekki Free Zone: 12,000 hectares of wetlands and mangroves converted. Without mangroves, coastal erosion intensifies. Villages in Ayetoro and Ogoniland are being swallowed by the sea. Saltwater now ruins 50,000 hectares of farmland annually.

Long-Distance Impact: Roads and Market Pressure

Opening Remote Forests

Ports need roads and rail links to move goods inland. Major projects include:

• Lagos-Ibadan Expressway upgrade

• Ajaokuta-Itakpe-Warri railway

• East-West Road across the Delta

Each kilometer of new road exposes 500 to 1,000 hectares of untouched forest to loggers and settlers. In Edo and Ondo States, sawmills line highways, supplying timber to Lagos markets.

Creating Demand for Timber

Lower transport costs from ports make wood exports more profitable. A log that once cost ₦15,000 to move now costs ₦6,000. This incentive drives deeper forest invasion. In Cross River, rosewood smuggling through Calabar Port has eliminated 90% of mature trees.

III. The Water Hyacinth Opportunity: From Invasive Weed to Forest-Saving Material

"The plant blocking our rivers can become the board building our schools."

Eichhornia crassipes—water hyacinth—infests over 60,000 hectares of Nigerian waterways:

• Lagos Lagoon: 12,000 ha

• Kainji Lake: 18,000 ha

• Niger Delta creeks: 25,000 ha

• Ogun River: 8,000 ha

It halts boats, kills fish, spreads disease, and harms livelihoods. But it doubles in size every 7–10 days and contains strong, usable fiber—making it a renewable alternative to wood.

Turning Water Hyacinth into Usable Fiber

The process is simple, local, and sustainable:

1. Collection: Fishermen and youth groups use floating cutters to gather the

plants.

2. Cleaning: Plants are washed in the same water to remove dirt.

3. Fiber Separation: Stems are softened with locally made soda ash to extract fibers.

4. Shaping: Wet fiber is pressed into sheets using solar-powered or manual presses.

5. Drying: Boards dry naturally in the sun or in basic kilns. No complex machines. No harmful chemicals. Fully powered by Nigerian sun and labor.

Strong, Practical Products

Bio-Boards for Construction and Furniture

These panels are:

• Denser and tougher than regular particleboard or plywood

• Naturally resistant to termites due to silica in the plant

• Smooth and ready for painting—perfect for school furniture, home roofing, and walls. They meet Nigerian quality standards (NIS) and work well in affordable housing projects.

Paper and Packaging

The fiber produces durable, bright paper for:

• Student notebooks

• Cement bags and food wrappers

• Tissue and toilet paper

All without cutting a single tree.

Composite Materials

Combined with cassava starch or palm waste binders, the fiber makes:

• Door panels

• Ceiling boards

• Market stall roofs

Restoring Ecosystems Through Use

This approach heals while it builds:

• Removing one ton of hyacinth frees 50–70 square meters of water surface.

• Each hectare harvested avoids 200–300 tons of CO e from forest clearing.

• Fish return, boats navigate, mosquito breeding drops, and forests face less pressure.

A single village-level processing site in Ogun State could:

• Clear 2,000 hectares of water per year

• Produce enough boards to build 500 school classrooms

V. Building Support: Policy and Community Leadership

Policy Actions Needed

• NESREA should recognize hyacinth harvesting as an official environmental service

• State governments must supply land and solar units for processing sites

• Education and Housing Ministries should require bio-boards in public buildings

• Traditional leaders should safeguard remaining sacred forests in return for community benefits from hyacinth hubs

Community-Led Model

• Cooperatives control production and tools

• Women's groups manage cleaning and drying

• Youth teams handle harvesting and pressing

• Elders oversee fair sharing of boards within villages

This strategy transforms Nigeria's interconnected crises—deforestation, infrastructure damage, and invasive weeds—into a unified restoration pathway, using local resources, community power, and ecological wisdom to secure a greener, more resilient future.

2.2 THE GREEN SHIFT IN MARINE ENGINEERING

The marine industry is at a crossroads, navigating a global push toward sustainability driven by environmental imperatives, economic pressures, and increasingly strict regulatory frameworks. The International Maritime Organization (IMO) has been instrumental in this shift, setting ambitious targets for decarbonization and waste reduction that compel the industry to re-evaluate its material choices (IMO, 2020). Traditional materials like fiberglass and aluminum, while effective, come with significant environmental baggage, including high energy consumption in production and limited end-of-life disposal options. This has paved the way for Natural Fiber Reinforced Composites (NFRCs), which are emerging as a compelling and eco-friendly alternative. Composite materials are those that are formed by the combination of two or more materials to achieve properties that are superior to those of their constituents (Nafaji et al, 2019). Polymer composites consist of a polymer resin as the matrix, with fillers as the reinforcement medium (Steckel et al, 2007). A typical composite materials matrix is shown in Figure 2.1.

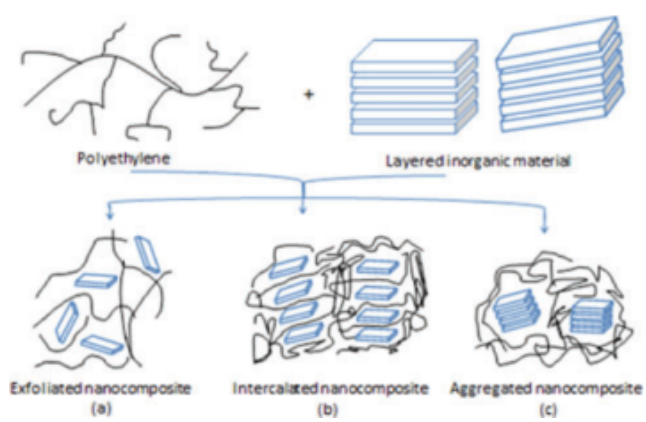

Figure 2.1 Composite (Khanam and AlMaadeed, 2015).

These composites, crafted from renewable plant based fibers, offer the potential for reduced vessel weight, improved fuel efficiency, and a sustainable environment

2.2 THE RISE OF NATURAL FIBER COMPOSITES IN MARINE APPLICATIONS

The adoption of natural fibers in marine engineering is a direct response to the global call for sustainable innovation. Fibers sourced from plants such as flax, hemp, jute, sisal, and kenaf offer a host of advantages over conventional synthetic materials. Their low density, biodegradability, and renewable nature make them an attractive substitute for glass and carbon fibers, particularly in non-structural components (Faruk et al., 2012). The integration of NFRCs into marine vessels directly contributes to weight reduction, which is a critical factor for improving fuel efficiency and reducing greenhouse gas emissions. This is especially relevant for tugboats, where enhanced maneuverability for towing and harbor operations is directly linked to a vessel's overall weight (Yan et al., 2016). Numerous studies have confirmed that NFRCs possess adequate mechanical properties for non-load-bearing applications. For instance, research on flax-based composites has showcased their successful use in yacht interiors, where they have achieved tensile strengths of 100–150 MPa while significantly reducing weight compared to traditional glass fiber composites (La Mantia & Morreale, 2011). However, the marine environment presents a unique set of challenges. The inherent properties of natural fibers, such as their hydrophilic nature, make them prone to moisture absorption, which can lead to swelling, material degradation, and a weakening of the fiber-matrix interface. Additionally, natural fibers are susceptible to microbial attack, and their flammability poses a significant safety risk. These issues necessitate specialized treatments and careful material selection to meet the industry's stringent safety standards, particularly the

IMO's Fire Test Procedures (FTP) Code, which sets strict fire resistance criteria for all marine materials (IMO, 2010).

2.2.1 What is Water hyacinth?

Water hyacinth (Pontederia crassipes, formerly Eichhornia crassipes) is a free-floating perennial aquatic plant native to the Amazon River basin in South America and is widely regarded as one of the world's worst and most problematic invasive aquatic weeds. It is well known for its extraordinary growth rate and ability to form dense, interlocking mats across the surface of freshwater bodies.

Physical Characteristics

Appearance: The plant has broad, thick, glossy, green, ovate or kidney-shaped leaves arranged in a rosette pattern. It can grow up to 1 meter (3 feet) in height.

Stems (Petioles): The leaf stalks (petioles) are a key identifying feature; in uncrowded conditions, they are spongy, inflated, and bulbous, acting as natural flotation devices (aerenchyma tissue) that keep the plant buoyant. In dense mats, these petioles become more elongated and slender.

Roots: The root system is dark, feathery, and fibrous, hanging freely in the water beneath the plant. These roots are efficient at absorbing nutrients and heavy metals from the water column.

Flowers: Water hyacinth produces a showy spike of 8 to 15 attractive, six-petaled flowers, typically lavender to blue-violet in color, with the uppermost petal featuring a prominent yellow, oval-shaped spot.

Reproduction: It reproduces both sexually through seeds (which can remain viable for 15-20 years or more) and asexually through horizontal runners or stolons that form daughter plants. Vegetative reproduction is the primary mode of spread and enables rapid colonization.

Invasive Nature and Ecological Impact

Water hyacinth's success as an invasive species outside its native range is due to its rapid proliferation and lack of natural predators. Under optimal conditions (warm temperatures and nutrient-rich water), a mat of water hyacinth can double its size in a matter of weeks, or its plant count can increase a hundredfold in just over three weeks.

The dense mats it forms have severe environmental and socioeconomic consequences:

Oxygen Depletion and Biodiversity Loss: The thick canopy blocks sunlight from reaching the water below, which inhibits the growth of submerged native plants and phytoplankton. When the shaded plants and older parts of the mat die and decompose, the process consumes vast amounts of dissolved oxygen in the water, leading to hypoxic or anoxic conditions that often result in massive fish kills and a significant loss of aquatic biodiversity.

Water Loss and Quality Degradation: The plant's high rate of evapotranspiration (water loss through leaves) causes water bodies to dry out faster than open water, impacting water availability for communities. The decaying matter also increases water turbidity and can cause secondary pollution. Disruption of Human Activities: The impenetrable mats impede boat navigation, fishing, swimming, and other recreational uses. They can also clog irrigation canals and damage intake pipes for drinking water and hydroelectric power generation facilities.

Public Health Risks: The dense mats provide ideal breeding habitats for disease vectors such as malaria-carrying mosquitoes and bilharzia-carrying snails, potentially increasing the incidence of these diseases in nearby communities.

Control Methods

Controlling water hyacinth is extremely difficult once established and typically requires an integrated management approach.

Manual/Mechanical Control: This involves physical removal of the plants by hand for small infestations or using specialized harvesting machines for larger areas. This is labor-intensive and costly but effective at reducing biomass.

Chemical Control: Herbicides (e.g., glyphosate, 2,4-D) can be used, but require careful application to avoid harming non-target species and causing water contamination.

Biological Control: Introducing natural enemies, such as specific weevils (Neochetina spp.) or moths, can help manage populations by stressing the plants and reducing their growth rate. This method is ecologically safer but slow to show significant results.

Beneficial Uses

Despite its classification as a noxious weed, water hyacinth biomass has various potential

uses:

- Phytoremediation: Its ability to absorb excess nutrients (nitrogen, phosphorus) and heavy metals makes it useful for treating wastewater and improving water quality in controlled

- environments.
- Biomass Products: The harvested plant can be used to produce biofertilizers, compost, biogas, and biofuels.
- Crafts and Other Materials: As shown in figure 2.2 and figure 2.3 Its fibrous stems can be used for making woven products like baskets, hats, and furniture, providing potential income opportunities for local communities.

Figure 2.2: Water Hyacinth being harvested for craft work

Figure 2.3: Craft work made from water Hyacinth

- Animal Feed: In some regions, the plant is harvested, dried, and used as a supplement in livestock feed, though high silica and mineral content need management.

In Nigeria, deforestation, marine infrastructure expansion, and water hyacinth invasion are not separate problems—they are a vicious cycle tearing at the nation's ecological and social fabric. Coastal ports and oil terminals destroy mangroves, opening the door to erosion and nutrient runoff. Inland, roads built to serve these ports slice through forests, enabling illegal logging and farmland conversion. Degraded watersheds then feed eutrophic rivers and lagoons, where water hyacinth explodes, choking waterways, killing fish, and blocking navigation.

But Nigeria holds the key to breaking this cycle. The same water hyacinth (Eichhornia crassipes) that clogs the Niger Delta, Lagos Lagoon, and Kainji Lake can be harvested, processed, and transformed into durable bio-boards, paper, and composites—materials strong enough to replace wood in furniture, housing, and construction. This is not a foreign import. It is a Nigerian-led, community-driven, ecologically restorative pathway that clears rivers, spares forests, and rebuilds resilience.

2.2.2 The Invasive Ecology of Water Hyacinth (Eichhornia crassipes) and the Coastal Threat Perimeter

The aquatic macrophyte Eichhornia crassipes (Mart.) Solms-Laubach, commonly known as water hyacinth, is globally recognized as the world's worst aquatic weed due to the significant ecological and cascading socioeconomic effects resulting from its proliferation. Originating in the Amazon River Basin of South America, the plant has been introduced to freshwater systems in over 50 countries, often initially as an ornamental species. Its success as a highly threatening invasive species stems from two primary factors: a formidable reproductive strategy and rapid growth rates. E. crassipes reproduces vegetatively through the formation of stolons, generating dense mats that double their biomass quickly. Furthermore, it utilizes sexual propagation, producing seeds that can remain viable in water for up to six years, making control and eradication exceptionally difficult.

Although water hyacinth is fundamentally a freshwater species, its invasive capacity extends significantly into transitional aquatic systems, including coastal rivers, deltas, and estuaries, which serve as crucial ecological and economic zones linking terrestrial watersheds to the marine environment. Within the United States, for instance, E. crassipes is widespread across the southeast, reaching north to Virginia and west to Texas, and has established itself in California and Hawaiʻi all regions defined by extensive coastal influence.

The presence of E. crassipes in these transitional zones dictates the definition of its coastal pollutant boundary. Research confirms that the species can tolerate salinity levels up to 0.24% (or 2.4 practical salinity units, PSU). This tolerance threshold ensures its viability within the low-salinity reaches of estuarine systems and large river deltas, such as the Sacramento-San Joaquin Delta in California and the Niger Delta in Nigeria.

The proliferation of water hyacinth is dependent on specific physicochemical conditions, thriving best in water with a pH between 6 and 8, and temperatures maintained between 10°C and 40°C. These parameters are frequently met in coastal and deltaic zones of tropical and subtropical regions. The dense, invasive mats do not remain static; they are transported by river flow and tidal currents. Therefore, the plant operates as an upstream vector of pollution; nutrient loading in freshwater areas promotes explosive growth, and the resulting biomass mats are then carried downstream into ecologically sensitive low-salinity estuarine habitats.

This phenomenon translates an inland invasive species issue into a significant downstream "marine" (brackish water) pollutant, with devastating effects on coastal fisheries and infrastructure.

The formation of dense, impenetrable floating mats by E. crassipes fundamentally alters the physical and chemical structure of invaded water bodies, transforming healthy aquatic ecosystems into stratified, deoxygenated systems. These changes constitute the initial and most immediate polluting effect.

Light Extinction and Primary Productivity Collapse

The most direct physical pollution mechanism is the obstruction of the water surface. The dense mats cause a drastic reduction in light penetration to the submerged column. This physical blockage, or light extinction, is highly detrimental to the base of the aquatic food web. The curtailment of light penetration inhibits the growth and productivity of phytoplankton and submerged vegetation. Phytoplankton are critical both as primary producers and as a major source of dissolved oxygen in the water column. Their collapse initiates a profound trophic disruption that ripples through the ecosystem. Furthermore, reduced light and dissolved oxygen alter the habitat for native vegetation and fish communities, thereby restructuring the ecosystem toward species tolerant of harsh conditions. Studies have shown that the dense structure beneath the mats can disrupt habitat for certain invertebrate groups, leading to comparatively low numbers of native invertebrate competitors.

Dissolved Oxygen Depletion and Hypoxia Induction

Water hyacinth is a primary driver of localized and widespread hypoxia (defined by dissolved oxygen (DO) concentrations too low to support aerobic aquatic life, typically below 2 mg/L) in transitional and coastal areas. This severe chemical pollution occurs via two interwoven mechanisms.

First, the physical mat acts as a respiratory pollutant by severely restricting the crucial process of gas exchange. The impenetrable mats block wind action and turbulent mixing, thereby limiting the natural diffusion and exchange of atmospheric oxygen across the air water interface.

Second, the mats are powerful biochemical sinks due to their high Biological Oxygen Demand (BOD). When plant tissues, particularly the fibrous roots and aerial biomass, die, their subsequent microbial decomposition consumes vast quantities of dissolved oxygen. The rate of this consumption varies depending on the tissue's composition; roots, for instance, contain high fiber content (up to 65%) and decompose much more slowly than aerial tissues, creating a persistent, long-term oxygen sink near the sediment interface.

The consequences of this DO depletion are observable and severe. While overall DO averages in fast-moving tidal systems may mask the effect , localized measurements confirm alarming levels of acute pollution. In invaded areas, the lowest observed DO value was (1.83mg), a concentration nearing the lethal threshold for many fish species, contrasted sharply with (5.84 mg) observed in adjacent uninvaded regions. This structural and respiratory pollution drives the ecosystem toward anoxia, representing a state of severe biological degradation.

Alteration of Water Column Physicochemical Properties

The massive biomass and decomposition rates associated with E. crassipes mats fundamentally shift the water body's chemistry. One key indicator of this chemical pollution is the significant increase in Total Dissolved Solids (TDS). Invaded areas have recorded TDS concentrations as high as (215.36 mg) dramatically exceeding the (24.208 mg) found in uninvaded regions. This increase is directly attributed to the release of high concentrations of organic matter and decay products from the thick, decaying mats, which pollutes the water with soluble breakdown components.

Furthermore, the intense decomposition and respiration processes beneath the mats contribute to elevated concentrations of carbon dioxide in the water. The dense vegetative cover can also suppress wind and wave impacts, leading to artificially lowered turbidity in low-flow areas. However, this perceived "clarity" is a false positive, as it supports enhanced surface cover and debris, paradoxically creating conditions conducive to greater water hyacinth growth and biological degradation, despite the lower sediment suspension.

Acceleration of Eutrophication through Nutrient Release

Water hyacinth exhibits a strong capacity for phytoremediation, rapidly assimilating nutrients such as nitrogen (N) and phosphorus (P) from contaminated water bodies. This attribute is often leveraged in remediation projects. However, this capacity transforms into a pollution liability upon the death of the plant. When the massive biomass decays, the assimilated nutrients are rapidly returned to the aquatic ecosystem. This continuous and often explosive cycle of absorption and subsequent rapid release of concentrated biomass contributes significantly to organic matter increases and nutrient loading, pushing the water body toward a eutrophic or hypereutrophic state. The high average chlorophyll-a concentrations observed in water hyacinth-invaded areas are directly linked to this altered trophic state, fueled by nutrient absorption and the ensuing influence of the dense mats on light levels. Fermentation of dead organisms in deltaic environments further reduces water quality.

Toxin Release Upon Decay: The Pollution Reversal Mechanism

If the water hyacinth biomass is not physically harvested and removed from the system, its ultimate decay drives a biogeochemical pollution reversal. The breakdown of plant material, which involves initial physical leaching followed by microbial decomposition , results in the severe remobilization of accumulated metal ions and toxins back into the aquatic environment.

This process contaminates water that might otherwise be clean, as the concentrated pollution is conveyed by water currents. The decay process is highly problematic because the primary site of heavy metal storage—the fibrous roots—decomposes slowly. This slow decomposition results in a persistent, long-term source of heavy metal leachate near the sediment interface, potentially impacting benthic organisms and sediment quality for years. The resulting pollution has direct biological consequences. Mercury accumulation in the food chain is a particular concern; exposed fish and other aquatic vertebrates struggle to excrete the metal, leading to bioaccumulation. This biological pollution can lead to neurological, hormonal, and developmental damage in vertebrates, manifesting as slowed response to predators in fish and reduced reproductive success in birds.

Impairment of Ecosystem Services in Tidal Environments

In tidal systems, the physical presence of water hyacinth mats significantly interferes with hydrological dynamics. In systems like the Sacramento-San Joaquin Delta, the mats disrupt normal tidal hydrology. This hydrological mechanism is key to the dynamic nature of the pollution; tidal action moves the water back and forth through the hyacinth patches, ensuring that the chemical effects of the pollution—such as localized changes in dissolved oxygen and turbidity—are dynamically exported both upstream and downstream.

This results in the creation of a continuous buffer of altered water chemistry surrounding the patches, meaning a localized infestation translates into a regional, spatially extensive zone of chemical pollution within the coastal area. Policy interventions based on remediation efforts are validated by the finding that water quality parameters, including dissolved oxygen and turbidity, only recover to regional averages after the water hyacinth has been treated and

removed.

Socioeconomic Pollution and Infrastructure Costs in Coastal Zones

The physical proliferation of E. crassipes constitutes an economic pollutant by severely degrading essential human infrastructure, maritime commerce, and livelihoods dependent on water access and flow dynamics.

Impairment of Maritime Transport and Navigation

The dense, large floating masses of water hyacinth act as a serious hazard, physically restricting access and clogging navigational routes, which negatively impacts fisheries and related commercial activities. This physical obstruction forces delta boat harbors and marine facilities to restrict operations, often resulting in damage to boats and facilities. For example, in the Niger Delta area of Nigeria, over 12,000 hectares of waterways have been infested since the 1900s, profoundly affecting the livelihoods of over 40 million people.

Impact on Coastal Fisheries and Livelihoods

The ecological degradation translates directly into severe socioeconomic stress. Water hyacinth reduces fish catchability and harvest yields, forcing communities that rely on fishing for their sustenance to abandon their livelihoods. The inability to reach fishing grounds blocked by impenetrable mats is a major cause of economic decline, exemplified by the situation in fishing towns like Cardano in the Philippines, where the local economy has been paralyzed.

The presence of the weed also increases the cost of fishing operations. Fishermen have reported that the cost of maintaining traditional boats following the weed infestation was twice as high as the corresponding figure prior to the water hyacinth invasion. This sharp increase in operational costs undermines the economic resilience of affected communities. This is shown in figure 2.4

Infrastructure Damage and Water Security Threats

As a physical pollutant, the mats pose a direct threat to critical infrastructure. Water hyacinth clogs the water intakes of power plants, water treatment facilities, and other industrial operations. Furthermore, the blockage of streams and drainage canals reduces their essential discharge capacity, significantly increasing the local risk of flooding in vulnerable deltaic and coastal areas.

The massive surface coverage by the plant also exacerbates water resource problems by increasing the rate of evapotranspiration, which alters the regional water balance. Estimates suggest that the flow of water into the creeks and rivers of areas like the Niger Delta can be reduced by up to one-tenth due to these increased losses.

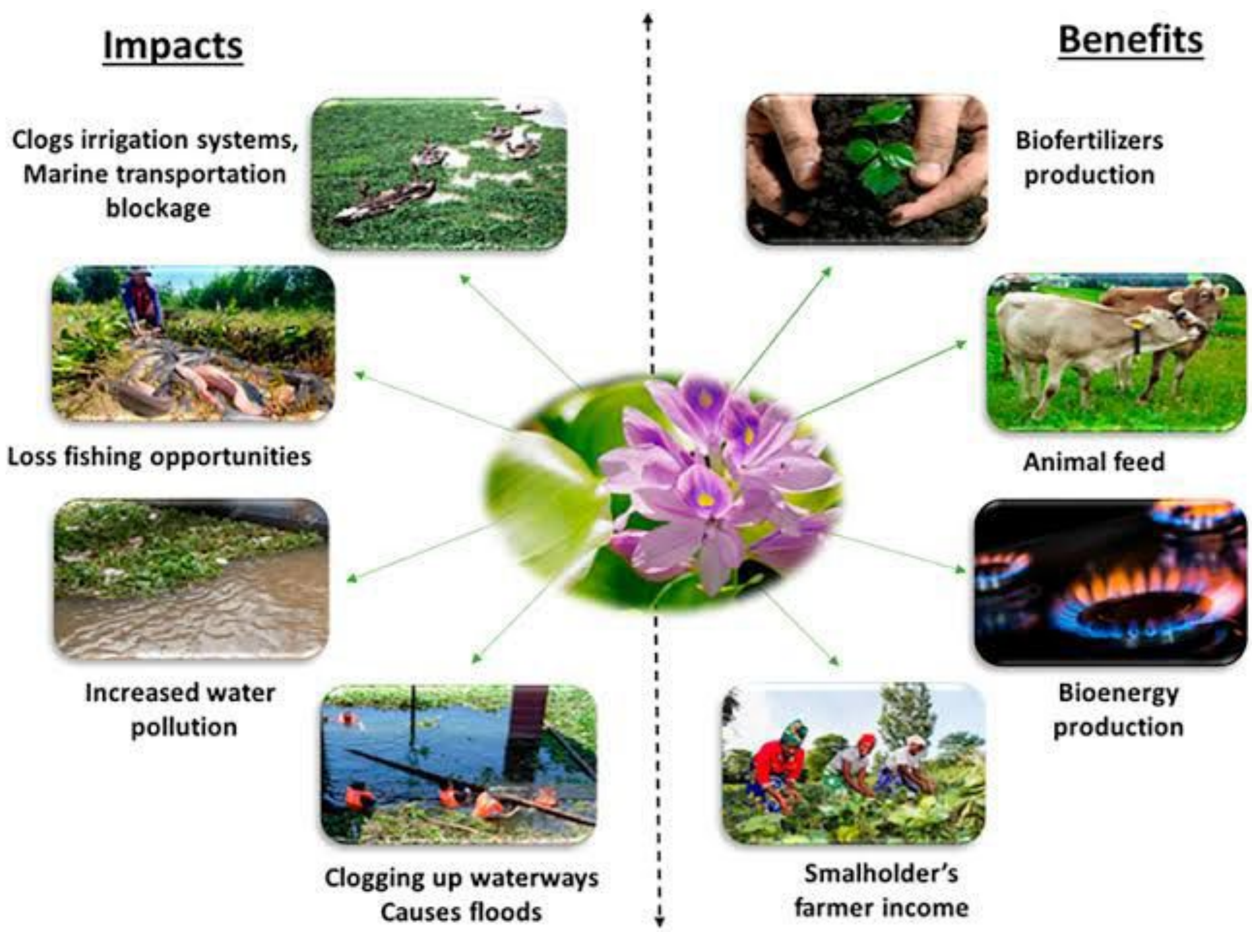

Figure 2.4: Chart on the impact and benefit of water Hyacinth

Hazards of Chemical Control Methods

Chemical control, involving herbicides such as glyphosate, 2,4-D, and paraquat, can rapidly reduce weed infestation. However, this method is generally the least utilized due to its longterm environmental and human health effects. The primary secondary pollution hazard arising from chemical control is the rapid, massive die-off of the plant biomass.

This sudden die-off causes a massive biochemical oxygen demand (BOD) as the biomass decays, leading to a sudden, severe drop in dissolved oxygen. This acute secondary pollution is highly detrimental to fish and other oxygen-dependent organisms, resulting in localized ecological collapses. While careful application and use of certain compounds in continuous flow environments might reduce the risk of herbicide dissipation , the risk of biochemical shock from decomposition remains high.

Physical Removal and the Disposal Dilemma

Mechanical removal via aquatic weed harvesters is widely recognized as the most effective short -term method for managing infestations. This strategy is critical because it removes the plant biomass before it can decompose and release accumulated toxins. Harvesting water hyacinth is deemed essential to control concentrations of pollutants like mercury. However, this process converts the aquatic biogeochemical pollution into a severe solid waste disposal problem. Because the plant has the capacity to accumulate heavy metals and other pollutants (Section 3.2), the harvested biomass must be managed as potentially contaminated waste. Improper disposal, such as burning or dumping uncollected agricultural by-products, can lead to serious health effects and environmental pollution, transforming the aquatic pollutant into a terrestrial or groundwater contamination source. The logistical complexity and cost of safely handling, transporting, and disposing of contaminated biomass represent a significant management challenge.

Integrated Management and Valorization

Effective control requires an Integrated Pest Management (IPM) approach combining mechanical removal with long-term biological control agents, such as the insect Megamelus scutellaris.

To safely mitigate the secondary pollution risk posed by the massive biomass waste stream, management efforts must focus on valorization—the conversion of harvested water hyacinth into value-added products, such as bioenergy or compost. Valorization allows resource managers to contain the concentrated pollutants removed from the water body while incentivizing the physical removal process, ultimately supporting a circular microeconomic model for pollution management and providing communities with economic resilience against the invasion. This text describes the detailed procedure for sourcing and preparing water hyacinth fiber for use as composite reinforcement. Here is a paraphrased and edited version for clarity and correct English.

2.3 APPLICATIONS, CHALLENGES, AND THE CIRCULAR ECONOMY

NFRCs have found their way into various ship interiors, from wall panels to furniture, primarily in luxury yachts and passenger vessels. For tugboats, the benefits are particularly pronounced: the lightweight nature of these composites directly translates to improved fuel efficiency, while their thermal and acoustic properties enhance crew comfort in a demanding operational setting (Yan et al., 2016). However, the literature has largely overlooked water hyacinth for these specific applications, focusing instead on more common fibers like flax and jute.

This leads to several critical research gaps and challenges that must be addressed:

1. Moisture Absorption: The inherent hydrophilicity of water hyacinth fibers is a major hurdle. Long-term exposure to the high humidity and salt spray of marine environments can lead to

reduced mechanical performance and premature degradation (Pickering et al., 2016). * Fire Resistance: The lack of established fire-retardant solutions and test data for water hyacinth composites prevents their widespread adoption in an industry governed by strict fire safety standards (IMO, 2010).

2. Scalability and Standardization: The absence of consistent quality control for fiber harvesting and processing, along with the lack of established industry standards for natural fiber composites, presents significant barriers to large-scale production and market entry (Faruk et al., 2012).
3. Long-Term Durability: There is a notable lack of research on the long-term performance of these composites when exposed to the corrosive and humid conditions of marine environments.

On a positive note, the use of water hyacinth aligns perfectly with the principles of the circular economy. By transforming an invasive weed into a valuable industrial material, this research supports ecological restoration and provides a sustainable, locally-sourced material, particularly in tropical regions where the plant is abundant (Sanjay et al., 2018). Furthermore, the production of these composites has a lower carbon footprint compared to synthetic alternatives, with emissions estimated to be 50–70% less than fiberglass (La Mantia & Morreale, 2011).

2.4 RELATED LITERATURES

Philip and Rakendu (2020) carried out a research study on the thermal insulation materials based on water hyacinth for application in sustainable buildings. The authors asserted that constant increase in environmental pollution and consumption of energy has prompted the construction industry to focus on thermal insulation. They also noted that non-renewable resources are commonly used for the production of thermal insulation materials. Therefore, a number of issues are being generated relating to the reuse or recycle of such materials. Also, a huge amount of energy is required for their production. The authors also cited that another major issue of concern was the aquatic weed infestation in water bodies. Invasive weeds such as water hyacinth (WH) are posing severe environmental as well as economic issues. A potential remedy for these waste disposal and high dependence on non-renewable materials are the conversions of these aquatic weeds into sustainable construction material. The primary objective of the research paper was to explore the utilization of WH petioles as a raw material resource for the production of thermal insulation material. The methodology to design the water hyacinth cement composite panel and its properties such as bulk density, water absorption, thermal conductivity, and flexural strength were included in the paper. The WH was collected; petioles were separated, sun-dried, milled into smaller particle sizes, and blend with a homogenous paste of cement and water. The homogenous mixture was poured into a mould and was compacted to produce the thermal insulation boards. The panel boards were made with water hyacinth particles that pass through 2.36 mm sieve. Water to water hyacinth ratio (w: WH) and the water hyacinth-cement ratio (WH: cement) used in the present work are 1.75 and 60: 40 respectively. In this paper, a comparative study between the thermal insulation materials made from WH with agro-waste based panel board and conventional thermal insulation materials are also included. This study indicates that WH biomass resources are a very good candidate for developing thermal insulation material and the correct combination of WH is absolutely comparable with conventional materials.

Ramirez et al., (2015) carried out a research on composites from water hyacinth (eichhornea crassipe) and polyester resin. The authors asserted that fibrous plants are available in abundance in nature and are a renewable resource. Hence the development of high performance composites from a cheap natural fiber, such as water hyacinth (Eichhornea crassipes) is particularly beneficial from an economic point of view. Remarkable, thermosetting resins such as polyester are used widely as a composite matrix due to polyester resins present a good dimensional stability, thermal stability, and good mechanical properties. As part of their study, some composites from water hyacinth fiber and polyester resin were prepared by using solution impregnation and hot curing methods. The composites were prepared by varying fiber percentages (5, 10, 15, and 20 wt%). These were characterized by FTIR and DSC analysis. Additionally, the elastic modules (MOE) from static test according to ASTM (D143-94) and by dynamic test from Sylvates Duo were obtained. Mechanical properties such as flexural strain and compression strength parallel of the different composites were analyzed. Thus, composites which had a concentration of water hyacinth in the range of 5 to 10 wt% yielded the best results. Additionally, the analysis showed no evidence of a negative effect on mechanical and thermal properties of the composite by addition of water hyacinth to the polyester resin. Furthermore, the results showed that water hyacinths fibres presented a competitive reinforcement quality when they were compared with other natural fibers, as such jute, abaca, and rice straw.

Khanam and AlMaadeed (2015) carried out study on processing and characterization of polyethylene based composites. The authors asserted that thermoplastic matrix polymer composites have gained commercial success in the semi structural and structural applications. Their review was designed for comprehensive source of PE-based polymer composites research, including structure and classification of PE manufacturing/processing techniques for PE composites, and it also described different characterization methods for PE composites. Differential scanning calorimetry (DSC) and thermos gravimetric analysis (TGA) characterization methods were used to describe the thermal properties of PE composites. Morphological studies were explained by using scanning electron microscope (SEM), transmission electron microscope (TEM) and atomic force microscope (AFM) techniques. Rheological properties and dynamic mechanical analysis (DMA) are also discussed in this review. X-ray diffraction (XRD) characterization was described in this review to explain crystallinity in PE composites. Hence, this review offers a comprehensive discussion on processing and characterization of PE-based composites.

Chris-Okafor *et al,* (2018), carried out composite material design of reinforcement of high density polyethylene with snail shell powder. As part of their research, the effects of snail shell powder on the mechanical properties and morphology of high density polyethylene, HDPE /snail shell powder composites were studied. The snail shell powder of particle size 83μm was incorporated into HDPE polymer resins at varying percentages of 0%, 5%, 15% and 25%. The test samples were prepared by using injection molding machine. The mechanical and morphological properties of high density polyethylene/snail shell powder composites have been characterized by an Instron machine in accordance with ASTM standard and optical microscopy respectively. From the results, hardness was observed to increase while the tensile strength, flexural strength and elongation at break decreased as the filler load increased. The result of the optical microscopy showed that the composites were more compatible than the unfilled composites. The filler improves the compatibility by finely dispersing the filler in the polymer matrix and a better interaction adhesion between the polymer matrix and filler particles.

Valente *et al,* (2021) explored the synthesis of biocompatible composite materials loaded with recycled porcine bone powder (BP) to fabricate scaffolds for in-situ reconstruction of bone structures. Polylactic acid (PLA) and poly("-caprolactone) (PCL) were tested as matrices in percentages from 40 wt% to 80 wt%. Chitosan (CS) was selected for its antibacterial properties, in the amount from 5 wt% to 15 wt%, and BP from 20 wt% to 50 wt% as active fillers to promote osseointegration. In their preliminary investigation, samples were produced by solvent casting to introduce the highest possible percentage of fillers. PCL was chosen as a matrix due to its greater ability to incorporate fillers, ensuring their adequate dispersion and lower working temperatures compared to PLA. Tensile tests demonstrated strength properties (6–10 MPa) suitable for hard tissue engineering applications. Based on the different findings (integration of PLA in the composite system, improvements in CS adhesion and mechanical properties), the authors supposed an optimization of the synthesis process, focused on the possible implementation of the electrospinning technique to develop PCL-BP composites reinforced with PLA-CS microfibers. Finally, biological tests were conducted to evaluate the antibacterial activity of CS, demonstrating the applicability of the materials for the biomedical field.

Agunsoye and Talabi, (2013) carried out study of the effects of cow bone filler on the microstructure and mechanical properties of recycled polyethylene/cow bone particulate composites. The effects of particulate cow bone additions on the mechanical properties and tribological behavior of cow bone reinforced polyethylene composite was evaluated to assess the possibility of using it as a new material for engineering applications. Cow bone particles reinforced with recycled low density polyethylene (RLDPE) was prepared by varying the cow bone particles from 5-25 wt% with 5 wt% interval using compression method. The mechanical properties of the developed composite were investigated. Scanning electron Microscopy (SEM) was used to examine the surface morphology of the composites. Wear of the composites were conducted using pin on disc machine by varying speed, time and load. Factorial design experiment was conducted as per standard 1.8 orthogonal arrays, with a view to investigate which of the design parameters; speed, load and time most significantly affect the dry sliding wear on the composites. The results revealed that tensile strength and the hardness values of the composite increases with increased in wt% cow bone particles while the impact strength and rigidity decreased. The study revealed that the additions of the particulate cow bone have the most significant main effect on the wear behavior of the composite while the interactions between load and time was not significant. The author concluded that cow bone particles could be used to improve the strength and wear properties of RLDPE.

2.5 POSITIONING THE CURRENT STUDY

This project is strategically designed to address the significant gaps identified in the existing literature. While the potential of NFRCs in marine engineering is well-documented, the specific application of water hyacinth remains largely theoretical. This study will move beyond theory by conducting a performance test on water hyacinth fiber and composite as a precept for a comprehensive material testing and will also provide a practical blueprint for integrating this innovative material into a more sustainable and efficient marine sector. Existing literatures clearly demonstrates the burgeoning role of NFRCs in creating a more sustainable marine industry. Water hyacinth, in particular, offers a unique opportunity to leverage an abundant, problematic resource for a positive environmental and economic impact. However, the path to its widespread adoption is currently blocked by critical challenges related to moisture absorption, fire safety, and a general lack of application specific data.

CHAPTER THREE

MATERIALS AND METHODS

3.1 MATERIALS

The materials and test required for the research PROJECT are listed in Table 3.1

Table 3.1 Materials requirements and tests for the research work.

	S/N	Materials	Units	Function
Literature work			Sum	General typesetting/literature research
	1	Water hyacinth	10kg	Composite base material
	2	Water	lump	Act as cleaning/mixing agent
Machines	3	Heat furnace	500^oC	For heat treatment and testing.
	4	Cooling trough	lump	For quenching
	5	Weighing scale	>25kg	For weighing masses.
Labor	6	Logistics/Service charges	Sum	Logistics/miscellaneous/wages
Test	7	Hydro bath		For specimen water absorption test

apparatus				
	8	Tea bags		For water absorption test
	9	Heat crucible		For thermal testing

3.2 METHOD

The method of approach of this project are as follows:

3.2.1 Materials Sourcing and Preparation

The preparation of water hyacinth fiber was carried out in the Materials Science Laboratory following the steps outlined below. The goal was to obtain a dry, pulverized water hyacinth powder suitable for composite reinforcement.

i. Water Hyacinth Sourcing from National Inland Waterways Authority (NIWA JETTY), Warri, Delta State

Water hyacinth (*Eichhornia crassipes*) was sourced from National Inland Waterways Authority (NIWA JETTY), Warri, Delta State. This site was chosen due to its high natural infestation and low industrial pollution, which ensured minimal chemical contamination of the plant material.

- **Harvesting:** Only healthy, green, and vigorous plants with intact roots and petioles were manually harvested using a machete and a long-handled rake. Decayed, yellowing, or insect-damaged specimens were discarded.
- **Initial Biomass:** Approximately **25 kg** of fresh biomass was collected.

- **Transport:** The harvested plants were gently shaken to remove excess river water and packed into breathable jute sacks to prevent anaerobic fermentation during transport. The material was delivered to the laboratory within four hours to maintain freshness.
- **Condition Check:** Upon arrival, the material had a slight earthy odor and showed no signs of decay.
- **Cleaning:** Removal of leaf and root, it was then washed to remove its offensive odour and dirt

ii. Preliminary Ambient Drying

The fresh biomass was first thoroughly rinsed under running tap water using a large plastic sieve to remove adhered mud, sand, snails, and epiphytic growth. Rinsing was repeated three times until the runoff water was clear.

- **Drying Conditions:** The cleaned plants were spread in a single layer on perforated plastic trays and placed in a shaded, well-ventilated area at ambient temperature (29–31°C) and approximately 68% relative humidity.
- **Procedure:** The material was turned every six hours to promote uniform air exposure.
- **Drying Endpoint:** Drying continued until no water dripped when the plants were gently squeezed, and no moisture marks appeared when pressed between filter papers.
- **Results:** Due to rainy and humid weather, this stage took two weeks. The initial weight of **25 kg** was reduced to **11.4 kg**, indicating the removal of **54.4%** of free surface water.

iii. Weighing After Preliminary Ambient Drying

A standard laboratory scale was used to weigh the ambient-dried biomass.

- A representative sample of **6.20 g** was taken for subsequent processing, documentation, and thermal stability testing.
- This weight was designated as $\mathbf{W_1}$, the weight after preliminary ambient drying.

iv. Oven Drying & Weighing

The **6.20 g** sample of water hyacinth was subjected to a stepwise oven drying process at increasing temperatures:

- The sample was dried at **100°C**, removed, and allowed to cool for one hour before proceeding.
- The same cooling process was repeated after drying at **200°C**, **300°C**, and **600°C**.
- The weight of the sample was recorded after each drying and cooling cycle (though the weights are not explicitly listed in this section).

v. Water Absorption Testing

A total of **2.86 g** of water hyacinth (which had been dried at **300°C**) was divided into four smaller portions for water absorption testing.

- **Sample Preparation:** The sample was divided into four parts and placed into separate tea bags for immersion:

  Bag 1: 0.74 g

  Bag 2: 0.69 g

  Bag 3: 0.73 g

Bag 4: 0.70 g

- **Testing Procedure:** After initial weighing, the tea bags containing the samples were immersed in water.
- **Measurement:** The samples were brought out and weighed again after a **24-hour** immersion period.

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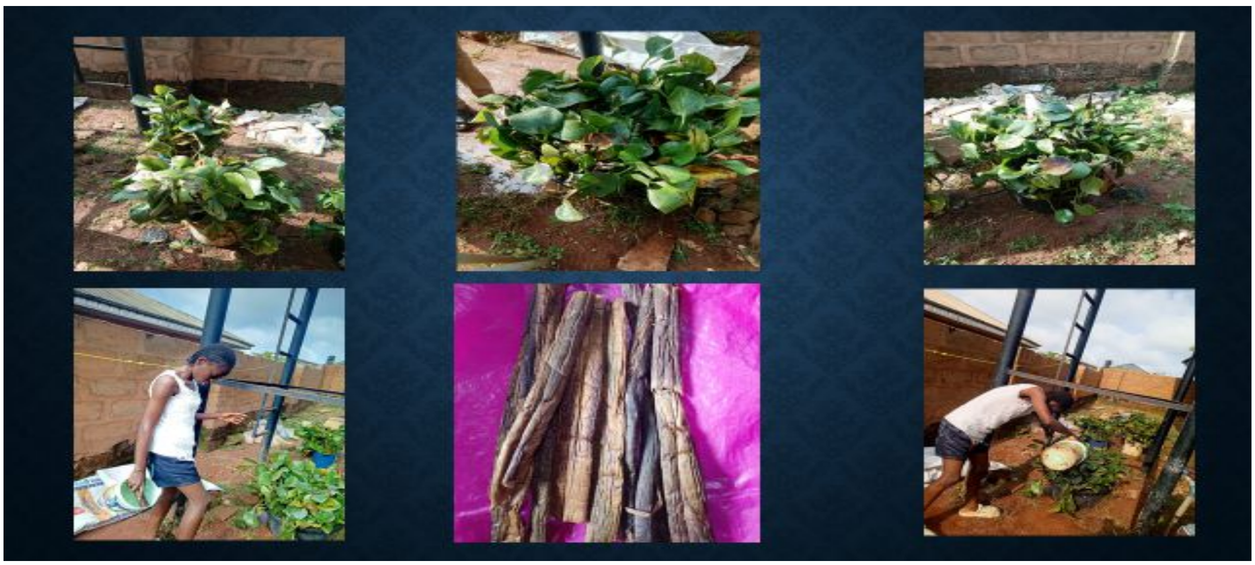

Figure 3.1: Project student harvesting, cleaning, and drying water hyacinth

3.2.4 Test

Test was carried out on the aggregate materials specimens in accordance with the test listed in section 3.1 is discussed as follows

1. **Thermal analysis of water hyacinth**

   Specimen was weighed prior to insertion into the drying furnace. The specimen was thereafter put on a furnace crucible and inserted into the furnace for onward heating and drying. Temperature reading of the furnace was taken at 100^0C increment from 0 to

300^0C and to 600^0C. A digital weighing scale was used to measure weight of the specimen before and after a run of furnace heating for every 100^0C temperature increase. Soaking of the specimen for 2 minutes at every terminal temperature was allowed to ensure uniformity in temperature. Physical examination of the specimen was carried out at the drying temperatures. The result of the thermal analysis is shown in Table 1.

2. Water Absorption

The water absorption was carried out to determine the ability of the material (labeled bag1 to bag 4) to absorb water at 300 degrees Celsius when immersed. The carbonized water hyacinth specimen was shared into 3 parts and stuffed into tea bags. The tea bags were immersed in water for 24 hours to determine the amount of water absorbed by the water hyacinth powder. Tea bags were used as a semi permeable membranous materials for water but not the much denser particles of the water hyacinth powder. This was necessary to prevent the water washing off the water hyacinth powder. The immersion of the tea bags containing the water hyacinth powder began at 1.49pm on 16th October 2025 to 1.50 pm 17th October 2025. This is shown in Figure 3.2 and Figure 3.3.

Figure 3.2: Water Hyacinth sample after 24 hours immersion in water

Figure 3.3: Water Hyacinth sample during immersion

Each samples initial weight before and after immersion were recorded. The percentage of water absorption was then calculated using this formula:

$$\% \text{ Moisture absorbed} = \frac{\textit{final weight of specimen - initial weight of specimen}}{\textit{initial weight of specimen}} \times 100 \qquad (3.1)$$

CHAPTER FOUR

RESULT AND DISCUSSION

4.1 Thermal Analysis of Water Hyacinth Specimen

The result of the thermal testing of the water hyacinth specimen is shown in Table 4.1

Table 4.1. Physio-thermal Analysis of Water Hyacinth

Weight of specimen (g)	Temperature (^{0}C)	Moisture loss (g)	Physical observation

6.20	0	0	 Specimen exhibited moisture texture, soft, dense and ductile with dark brown color.
5.01	100	1.19	 Specimen becomes light brown with small patches of dark brown probably showing gradual loss of moisture. Ductility was reduced.
Weight of specimen (g)	**Temperature (^{0}C)**	**Moisture loss (g)**	**Physical observation**
4.62	200	0.39	

			Specimen is hard, reddish-dark-brown patches typical of dry-wet interface consistent with evaporation process.
2.60	300	2.02	 Specimen became hard, dark, crispy-brittle, disintegrated to ashes on slight mechanical rubbing or impact.
NA	600	NA	 Specimen completely burnt out to darkish-brown smoot textured ashes.

4.2 Water Absorption Analysis

The result of the water absorption test is shown in Table 4.2

Table 4.2 Water Absorption Test Result

	Bag 1	Bag 2	Bag 3	Bag 4

Initial weight(g) before immersion	0.74	0.69	0.73	0.70
Final weight(g) after immersion	5.66	4.98	5.53	4.75
Difference(g)	4.92	4.29	4.80	4.05
% moisture	664.86	621.74	657.53	578.57

From the date recorded in Table 4.2, the amount of water absorbed the water hyacinth specimen were determined as follows:

For bag 1

$$= \frac{5.66 - 0.74}{0.74} \times 100$$

= 664.86%

For bag 2

$$= \frac{4.98 - 0.69}{0.69} \times 100$$

= 621.74%

For bag 3

$$= \frac{5.53 - 0.73}{0.73} \times 100$$

= 657.53%

For bag 4

$$= \frac{4.75 - 0.70}{0.70} \times 100$$

= 578.57%

Inference made from the outcome of the test carried out on the specimen showed the followings:

1. There were critical limitations of water hyacinth as a composite reinforcement material.
2. The material cannot be carbonized due to its low thermal stability, and it absorbs excessive moisture (668%), making it unsuitable for some marine interior applications.
3. These findings are important because they guide future sustainable materials research and prevent the use of ineffective processing methods."

Owing to the preliminary basic tests carried out on the water hyacinth specimen, coupled with time and financial constraints, the research was adjudged inconclusive in some respects with further works proposed to determine other mechanical properties of the prepared composite specimens of water hyacinth and saw dust and water hyacinth and polymer dust.

CHAPTER FIVE

CONCLUSSION AND RECOMMENDATION

5.1 CONCLUSSION

The project was successfully executed to show that water hyacinth though abundantly available in Nigeria water body, its use for ship interiors making may be limited by its poor thermal stability and high water absorption. Some limitations were faced in a bid to carry out a comprehensive materials properties and testing of water hyacinth and its composite. These limitations include the followings:

i. Insufficient Temperature Control during Carbonization: The absence of a programmable digital kiln limited the ability to control and monitor the heating rate and temperature during fiber carbonization, which likely led to complete burning of the water hyacinth samples.

ii. Access to high-cost machinery like SEM (for microstructure investigation) was restricted, limiting essential marine suitability tests.

iii. Insufficient capital limits the purchase of specialized equipment and necessary raw materials (resins, treatments).

iv. High Moisture Sensitivity of Fibers: The strong hydrophilic nature of water hyacinth fibers made it difficult to achieve stable fiber matrix bonding. Even after drying at 250°C and 300°C, the fibers quickly reabsorbed moisture from the environment before resin mixing, affecting the final composite quality.

v. Environmental and Time Constraints: The retting and drying processes depended on environmental conditions and available lab time. Variations in humidity and drying time affected the uniformity of the extracted fibers and introduced inconsistencies in the final composite samples.

vi. Limited Material Characterization: Due to time and resource constraints, only a few mechanical tests (thermal stability, and water absorption) were carried out. Other important analyses such as impact strength, fire resistance, and chemical resistance could not be performed, which might have provided a broader understanding of the composite's potential.

5.2 RECOMMENDATION

As part of a crucial recommendation, the following recommendations are made:

i. This research should be comprehensively carried out to use and test different materials composite combination with water hyacinth.

ii. A comprehensive mechanical testing should be proposed to further carry out extensive materials testing and characterization of water hyacinth in combination with other materials such as egg shell powder, silicone dioxide (sand), periwinkle shells and a host of other materials.

iii. The present research study can be extended to further include the use of the water hyacinth and other materials combination composite to produce a proof of concept of a marine vessel accessory which can be tested for its suitability for deployment in a real marine vessel.

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