ECOLOGICAL INNOVATION: THERMOSETTING RESINS AND WATER HYACINTH FIBER IN HIGH-PERFORMANCE BIO-COMPOSITE MATERIALS FOR SUSTAINABLE WASTE MANAGEMENT

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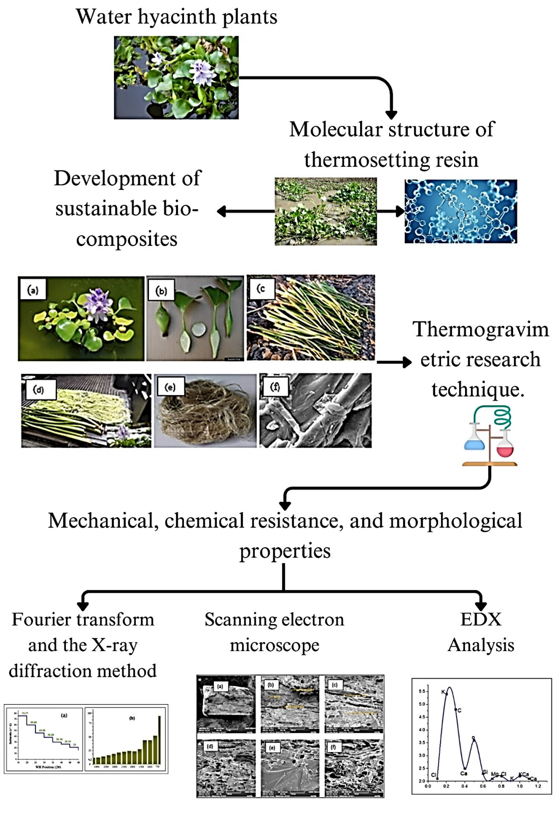
Graphical Abstract



Abstract

Fibrous plants represent a sustainable and abundant natural resource with significant economic and ecological advantages for developing high-performance composites. Utilizing cost-effective natural fibers, particularly water hyacinth (Eichhornia crassipes), in composite matrices with thermosetting resins such as polyester is common due to their superior dimensional stability, thermal resistance, and mechanical properties. In this study, composites were fabricated using hot curing and solution impregnation techniques, combining water hyacinth fibers with polymer matrices. The primary aim is to investigate how the incorporation of PVC and bio-composite components alters the texture and properties of these materials, particularly focusing on the effects of fiber-reinforced nanoparticles in polymer matrices. The research emphasizes water hyacinth as a bio-composite material, typically prevalent during river overflow conditions. The crystallinity index of water hyacinth fiber composites was found to be 54.82%. Detailed examination of the composite's surface morphology was conducted using transmission electron microscopy, while thermogravimetric analysis assessed its thermal degradation properties. Furthermore, the study aims to evaluate the mechanical strength, chemical resistance, and morphological characteristics of these composites, contributing to a comprehensive understanding of their potential applications and environmental benefits.

Keywords: Water hyacinth, hemicellulose, fiber composite, bio-composite, reinforcement.

1. Introduction

A substance that is created by combining two or more unique components is referred to as a "composite." In general, a composite material is any substance made up of two or more parts, each of which has unique qualities and clear boundaries between them. Polymer composites are made up of a continuous polymer matrix and one or more discontinuous phases.

Reinforcement is the term for the discontinuous phase, which is typically harsher and more powerful than the continuous phase. Natural resources are being heavily mined as an alternative to manmade materials due to the rise in pollution and environmental hazards. As a result, the use of natural fibres for composite reinforcement has drawn more and more attention. Incomparable advantages over synthetic fibres exist for natural fibres.

In recent years, the quest for sustainable solutions in material science has intensified, driven by the urgent need to mitigate environmental impact and manage resources more responsibly. Amidst this backdrop, the exploration of bio-composite materials represents a promising avenue for ecological innovation. This study focuses on the integration of water hyacinth fiber, sourced abundantly from natural water bodies, with thermosetting resins like polyester. By harnessing these renewable materials, this research aims to develop high-performance bio-composite materials that not only exhibit excellent mechanical and thermal properties but also contribute significantly to sustainable waste management practices. This introduction sets the stage for a comprehensive exploration into the ecological benefits and technological advancements of utilizing water hyacinth fiber and thermosetting resins in bio-composite materials, paving the way towards a more sustainable future.

Water hyacinth can offer value by being used to create furniture, handicrafts, paper, and a medium for straw mushrooms. The use of composite materials is now expanding quickly. The composite's advantage of being easily produced encourages the usage of composites in place of metal materials in a variety of goods. Natural fibre reinforced matrix polymer composites are in high demand because of their numerous benefits, including low density, affordability, availability, and biodegradability. A bio-composite is a composite that uses natural fibres as reinforcement. Compared to plastics, it has better ecological effects. They encourage the mechanical qualities to be improved. For the engineering application, the materials were suitable.

The water hyacinth is a readily available natural component in India that has not been fully researched. The bio-composite hyacinth has been used repeatedly to create inexpensive composite materials that also meet technical standards, particularly for motorcycle helmets. Helmets for motorcycles are a safety item that can be used in transportation to guard against head injuries. In contrast, motorcyclists are the mode of transportation with the lowest level of driver protection, particularly for the head, and the highest risk of traffic accidents. It is crucial to pay close attention to efforts to increase the safety of drivers, especially those involving helmets. Helmets are not only safety equipment; they also need to be as comfortable and safe as possible for the wearer in order to prevent and lessen head injuries caused by impacts in traffic accidents.

The weight percentage and substrate type of lignocellulose-polymer composites were found to be important determinants of the composites' characteristics in recent studies aiming at generating high-performance composites. Natural fibres are a useful class of materials that are also renewable, biodegradable, and good to the environment because of their natural state. Compared to other fibres, the water hyacinth includes a higher percentage of holocellulose, making it an excellent choice to use as a reinforcement material. A variety of natural fillers, like water hyacinth, can be combined with synthetic polymers to increase their physico-mechanical properties and get the qualities required for certain applications. Thus, lignocellulose polymer composites were created using conjugated polyester and ground water. Using differential scanning calorimetry, the impact of the water hyacinth fibre on the composites' thermal and mechanical properties were examined (DSC). Fourier transform infrared spectroscopy was also used to conduct a structural investigation.

Water hyacinth (WH), which contains lignocellulose components such cellulose, hemicelluloses, and lignin, is one of the natural fibre sources. A lignocellulosic material is anything that contains both cellulose and lignin. It is a plentiful source of renewable polymers that are also very biodegradable in nature. Nutrient contents, particularly nitrogen, are directly connected with the growth of water hyacinths. Rising nitrogen and phosphorus levels have an impact on biomass accumulation, ramet production, shoot: root ratio, and plant height. But in eutrophic water bodies, such as South Africa's Bon Accord Dam and Hartbeespoort Dam, as well as other areas of its introduced area, water hyacinth has developed significantly. The primary objective of the study is to develop high-performance bio-composite materials using thermosetting resins and water hyacinth fibers. The research questions focus on assessing the mechanical properties and sustainability of these materials, and evaluating their effectiveness in sustainable waste management practices.

In (Jirawattanasomkul et al. 2021) the construction industry, recycling methods and the usage of eco-friendly building materials are growing in popularity. There are drainage problems in many countries as a result of the water hyacinth's rapid spread in natural rivers and canals. As a result, it costs the local organisations a lot of money each year to get rid of the water hyacinth wastes were discussed. (Tan & Supri 2016) defines that low-density polyethylene/natural rubber/water hyacinth fibre (LDPE/NR/WHF) composite characteristics were examined after alkaline treatment. Utilizing a Brabender Plastic order, composites made of LDPE/NR/WHF and LDPE/NR/WHFNaOH were created.

(Bekalo and Sharma 2022) provide a thorough analysis of the use of water hyacinth in composite materials as a natural reinforcement. The paper highlights the potential of water hyacinth fibers to improve the mechanical characteristics and sustainability of the produced materials by discussing their different processing methods and uses in the fabrication of composites. The writers examine current developments, obstacles, and opportunities in the use of water hyacinth fibers, stressing the material's advantages for the environment and the economy. Researchers and practitioners interested in sustainable composite materials using natural fibers may find this review to be a useful resource.

As part of the mechanical extraction process, the outer stems of the water hyacinth were first grated using a semi-automatic fibre extraction machine. The water hyacinth fibres were between 30 and 50 cm long, with a diameter of about 50 m. The operation resulted in an even surface texture with the highest amount of split fibres using the mechanical way of fibre extraction, followed by the chemical method that analysed in (Chonsakorn et al. 2018).

(Ajithram et al. 2022) represents that Hyacinth long fibre composites have mechanical strengths that range from 36.42 to 44.62 MPa in tensile strength, 47.86 to 59.684 MPa in flexural strength, and 0.5 to 3.5 J in impact strength. Hyacinth fibre composite is strongly advised for use in profit-oriented items based on the results of the final trial.Economically, the creation of high-performance composite materials made of inexpensive natural fibres like water hyacinth is particularly advantageous. As a composite matrix, remarkable thermosetting resins like polyester are frequently utilised because they have excellent mechanical and dimensional stability. Aluminium powder and polyester resin were created for the 7 different weight ratios of water hyacinth fibre composites utilising solution impregnation and heat curing techniques explained in (Padmanabhan et al. 2016).

Water hyacinth (Eichhornea crassipes) is one of the cheapest natural fibres that is readily available to humans and has not yet been thoroughly investigated. Water hyacinth can be utilised as filler in a variety of polymer matrices for composite products. Water hyacinth fibres were used as reinforcement and epoxy resin (ADR 246 TX) as the matrix for this composite composition demonstrated in (Huda et al. 2017).

(Ibrahim et al. 2022) examine the mechanical and physical characteristics of polymer composites enhanced with water hyacinth fibers. The influence of water hyacinth fibers on the composite materials' tensile strength, flexural strength, and impact resistance is assessed in this research. The inclusion of water hyacinth fibers improves mechanical qualities, according to experimental data, indicating its potential for structural applications. The study supports the development of these composites as sustainable alternatives in a variety of industrial sectors by providing important data on their performance characteristics.

(Syafri et al. 2019) discussed about Sago starch (SS) biocomposites have been explored with cellulose microfibers (CMF) generated from water hyacinth (WH) fibre as filler. Acid hydrolysis, bleaching, and pulping techniques were used to remove the CMF. The CMF addition rates for the sago matrix were modified to 0, 5, 10, 15, and 20 wt%.Biocomposites were produced using solution casting and glycerol as a plasticizer. The biocomposites were also identified using X-ray, FTIR, SEM, thermo gravimetric, tensile testing, soil burial tests, and other techniques.

(Sindhu et al. 2017) denotes that composites were spreads quickly and adversely affects the growth of both plants and animals by robbing water bodies of their nutrients and oxygen, water hyacinth is widely regarded as a noxious weed around the world. Therefore, turning this undesirable weed into valuable chemicals and fuels aids in developing countries' ability to sustain themselves. Water hyacinth has attracted a lot of interest in the creation of biomethane, biochar, biogas, biohydrogen, and its use in the treatment of wastewater. The creation of integrated decentralised water systems and the manufacture of the most valuable and high-quality goods, such biochar used in power generation, still require even more careful thought, which explained in (Gaurav et al. 2020).

(Bordoloi et al. 2018) says that one of the hardest-to-control and invasive weed species is water hyacinth (WH). The effectiveness of this species as charcoal (BC) in enhancing soil fertility and metal adsorption has been the subject of recent investigations. However, research on the soil-WH biochar composite's soil water retention (SWR) characteristic and crack propensity is still lacking.Water hyacinths (Eichhornia crassipes) are a potential contender for fuel ethanol generation in tropical countries due to their high biomass yield and wide availability. With the appropriate technological approach, such biomass could be responsibly bioconverted to bioethanol in (Das et al. 2016).

Particles of hyacinth powder have not been thoroughly investigated in (Arivendan et al. 2023) polymer composites. The main goal of this project is to produce composite materials from hyacinth powder utilising eggshell powder. Hyacinth powder is used to enhance the mechanical characteristics of composites. By using a matrix made of an epoxy polymer and the powder particles, compression moulding is employed to create composite samples. Around the world, Eichhornia crassipes, a weed, is a typical sight in lakes, rivers, and other bodies of water. Water bodies with water hyacinth infestations are typically challenging to clean up due to their high rates of regeneration, survival, and growth explained in (Guna et al. 2017).

(Ali and Hassan 2022) investigate water hyacinth-based sustainable natural fiber composites. The paper discusses the biodegradability and low carbon footprint of water hyacinth fibers in comparison to synthetic alternatives, as well as the environmental advantages and applications of these fibers in composite materials. The study assesses the mechanical, thermal, and morphological characteristics of composites made of water hyacinth, indicating their potential as environmentally beneficial building and packaging materials. The results highlight the viability of using water hyacinth fibers into environmentally friendly composite manufacturing, encouraging resource efficiency in the fabrication of materials and protecting the environment.

(Tanpichai et al. 2022) express to create nano fibrillated cellulose; water hyacinth (Eichhornia crasspies) was employed as a renewable cellulose source (NFC). Due to the water hyacinth's porosity structure and low lignin concentration, disintegrating nanofibers only required a 10-minute treatment utilising high-speed homogenization. According to (Carreño-Sayago 2021) Eichhornia crassipes has a high potential for bio adsorption in its vegetative structure and retains heavy metals. In order to remove chromium from tannery water, this study aims to create microspheres from the dried and ground biomass of E. crassipes roots. These microspheres will then be combined with sodium tripolyphosphate. Methodology of fiber is shown in figure 1.

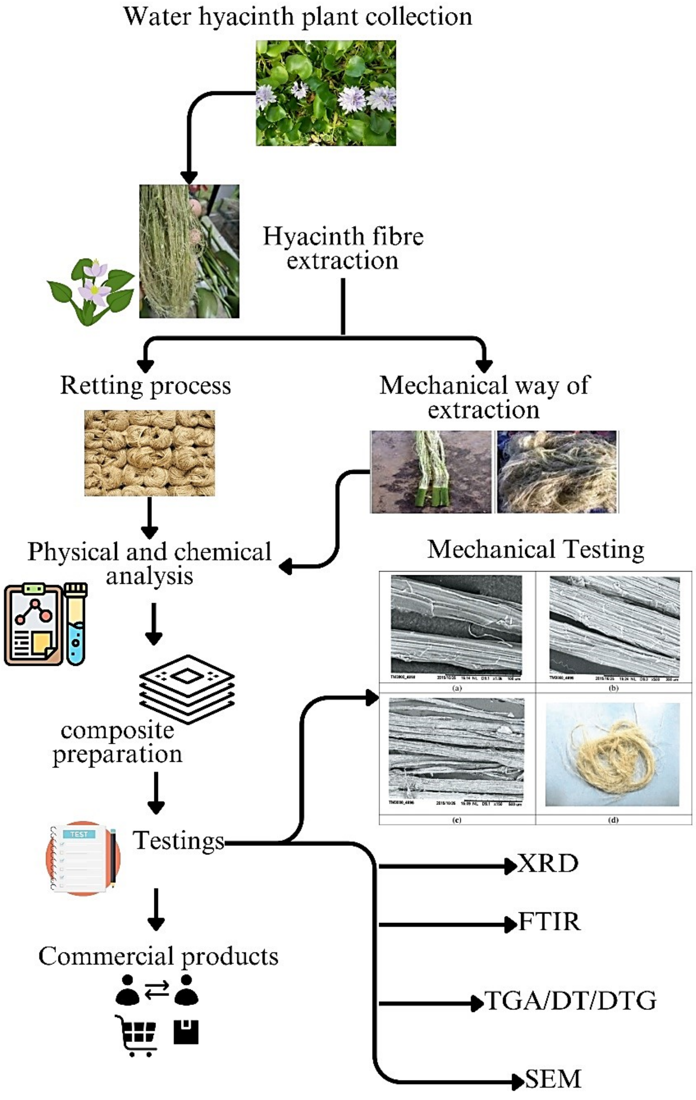


Figure 1. Methodology for water hyacinth fibre composites.

The composites were created by impregnating water hyacinth fibers with various thermosetting resins (epoxy, phenolic, and polyester) using a solution impregnation process. The textures of the composites were analyzed using scanning electron microscopy (SEM) to assess fiber-resin bonding and surface morphology.

2. Methods and materials

2.1 Materials

The hyacinth plants are harvested from the neighbouring water bodies in Tamil Nadu, India's Trichy district lakes. The plants are divided into their component parts after being gathered. Epoxy and hardener are secondary materials that are obtained from Covai Seenu & Company in Tamil Nadu, India.

2.2 Composite Specimen Preparation

Fiber from water hyacinths was just being gathered in the nearby Patzcuaro Lake, Mich., Mexico. The composites were created using five, ten, fifteen, and twenty weight percents of fibre loading, with ten copies manufactured for each concentration. The ingredients had to cure for 20 days at 22 ºC after being placed in 30 x 22 x 22 cm moulds. They were then taken out of their moulds.

2.3 Woven Fiber Water hyacinth

Take a about 40 cm tall water hyacinth plant. Select top-notch water hyacinth plants. After being cleaned of filth, plants should dry in the sun for ten days as shown the figure 2. The Semarang Ministry of Industry then took a measurement of the moisture content.

Figure 2. Woven Fiber Water hyacinth

2.4 Water Hyacinth Powder

Make ready the dried water hyacinth. 2 cm of water hyacinth fibre are cut. The fibre is then combined till it is powder. The powdered water hyacinth was then sieved using a 140 mesh sieve to a size of around 0.1 mm as shown the figure 3 [a] and [b] .

Figure 3. 140 meshes sieve and Water Hyacinth Powder

2.5 Epoxy resin with hardener Matrix

Epoxy has excellent mechanical qualities. It is very resistant to chemicals and heat. Low viscosity makes it feasible to thoroughly moisten the fibres and avoid irregular fibres during processing. Low shrinkage rates that lessen the likelihood of a strong shear stress bond between the epoxy and the reinforcement.

2.6 Methods

2.6.1 Physical and chemical analysis of water hyacinth

An optical microscope was used to measure the size of the hyacinth plant at five separate locations, with 25 overall average and 40x resolution. Additionally, the density of plant fibres is measured at room temperature. Water hyacinth plant fibre is combined with various amounts of epoxy matrix material for mechanical testing. A hot pressing injection moulding machine is also used to press the sample. The tensile, flexural, and contact strength of the sample are evaluated using a Charpy impact testing device and a Universal testing machine after the manufacture of the water hyacinth natural fiber. Three samples are used for each test, and the results contain the average value. As for the impact test, flexural test, and tensile strength test, this study complies with ASTM D256, D790, and D3039 standards, respectively.

2.6.2 Test for chemical and water absorption

In accordance with ASTM guidelines, the water hyacinth composite specimen is combined with 100 mL of water and chemical samples of NaCl and NaOH. The composite sample is continuously measured for up to 60 hours. For a maximum of ten hours, the composite sample's final results are monitored every two hours. Every five hours, the sample weight for the remaining 50 hours is determined. The ASTM D570 and C413 standards were followed for all water and chemical absorption testing.

2.6.3 Thermo gravimetric analysis

The furnace that this analyzer is accompanied by has a crucible that is supported by precise balancing. The temperature range for the sample is 10° to 600°C, with a heating rate of 10°C/min. The flow rate of nitrogen gas to the furnace is 20 mL/min.

3. Result and discussion

3.1 Water hyacinth physical and chemical analyses

Typically, the mechanical, biodegradable, and fire-retardant qualities of natural fibres determine their chemical composition. The mechanical strength of the fibre, particularly its tensile strength and modulus, is enhanced by the amount of cellulose present. However, the hemicellulose component reduces the fiber's tensile and flexural strength. One of the factors influencing the structure of water hyacinth fibre is the small quantity of hemicellulose present. The wax content in water hyacinth is at a minimum (0.35%) compared to other natural plant fibres. The hyacinth fibre has a 0.3965 mm diameter. The diameter of a water hyacinth is explained in detail in Figures 4 (e) and (f).

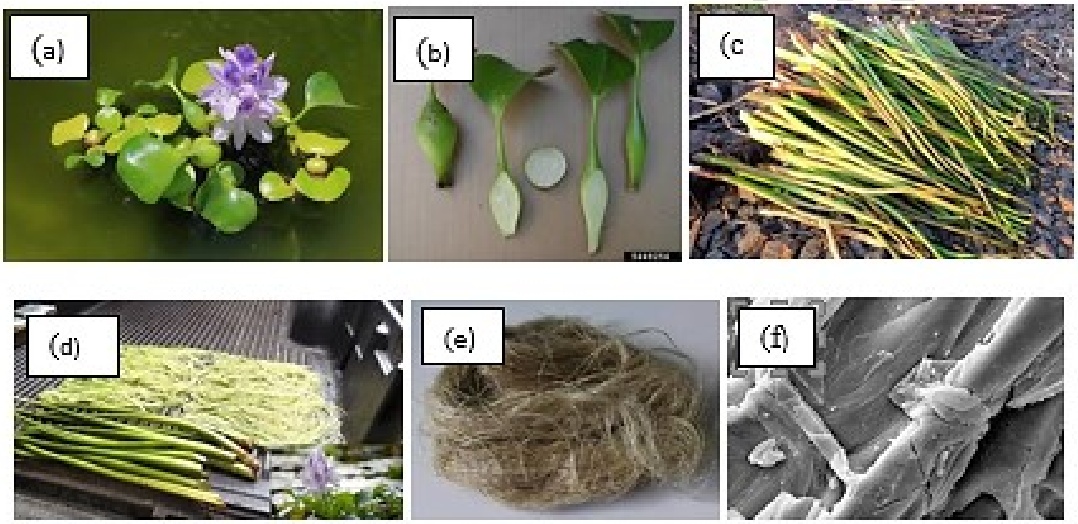


Figure 4. **(a)** Water hyacinth plant, (b) petiole, stem,(c) stem (d)extracted stem, (e) fibre structure after sunlight and (f)optical microscope image of the fibre.

The water hyacinth, or Eichhornia crassipes, is abundantly available natural resource for producing high-performance composites since it is widely distributed in aquatic habitats in tropical and subtropical parts of the globe. Its quick development and capacity to flourish in a variety of aquatic environments add to its raw material sustainability. Water hyacinth's fibrous nature makes it a good material for composite applications, providing chances to improve stiffness, strength, and durability. In addition to making use of a renewable resource, the unrestrained expansion of water hyacinth in natural environments poses environmental concerns that are addressed by using it in composite production. Water hyacinth therefore offers a potential path for creating composite materials that are both environmentally and commercially sustainable.

3.2 Mechanical Testing

Natural fibres from the parent plant of the water hyacinth are removed, and then various weight percentages of epoxy resin matrix material are added. The length of this hyacinth fibre is 10 mm. The suggested hardener and matrix are LY556 and HY951, respectively. A 10:1 ratio is used to blend the hardener and matrix. There are numerous ratios in which hyacinth fibre reinforcement is incorporated, including 15, 20, 25, 30, and 35%.

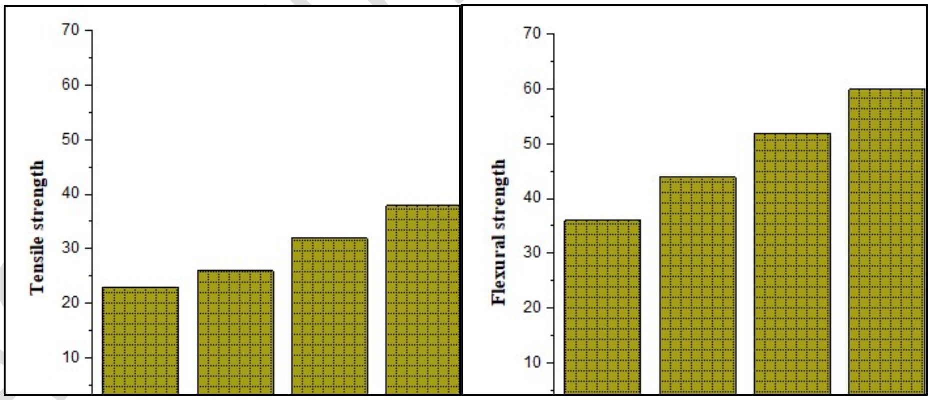
Table 1. Statistics on water hyacinth fibre composites.

Water hyacinth fiber composite tensile test statistical data				
sample percentage	tensile strength mean (Mpa)	Tensile modulus (Mpa)	Tensile strength standard deviation	tensile strength co-efficient of variation
26%	33.52	4377		32.725
31%	36.47	4753	4.35	25.78
36%	42.96	4965	3.79	24.67
41%	40.76	5175	8.67	24.55
46%	44.35	4879	3.45	33.525
Water hyacinth fiber composite Flexural test statistical data				
sample percentage	flexural strength mean (Mpa)	Flexural modulus (Mpa)	flexural strength standard deviation	flexural strength co-efficient of variation
26%	47.96	5147	4.29	29.75

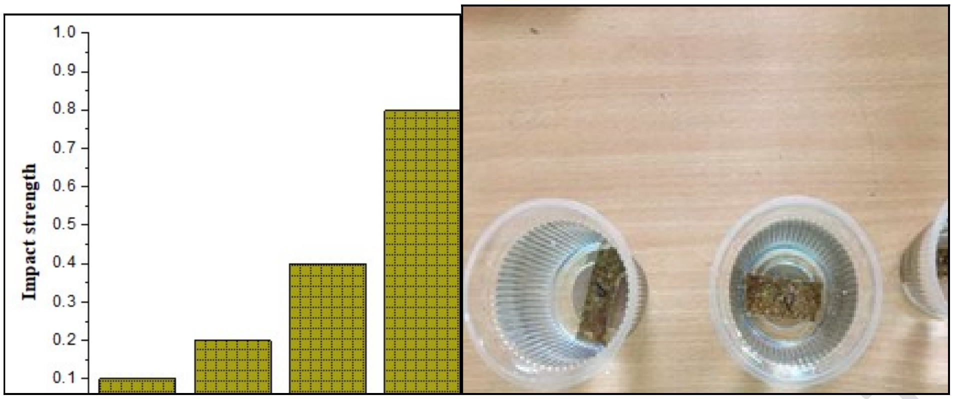
31%	56.5	5553	4.57	33.69
36%	63.46	5271	3.29	27.59
41%	71.23	5879	6.67	32.47
46%	66.43	5315	3.37	33.69

The sample is sliced according to ASTM D256 for impact, ASTM D790 for flexural testing, and ASTM D3039 for tensile testing. Using appropriate standards, the mechanical strength of raw epoxy composite was also evaluated. Up to 30% more of the appropriate weight increases the fiber's mechanical strength. After 30%, adding more reinforcement causes the mechanical strength to decline. These findings demonstrated why applications requiring lightweight materials should use hyacinth fibre reinforcing at a 30weight percentage. The water hyacinth natural fibre composite's tensile, flexural, and impact strengths were shown in Figure 5. (Table 1).

3.3 Water and chemical absorption test



(a) (b)



(c) (d)

Figure 5. (a) Tensile test, (b) Flexural test, (c) Impact test, (d) Absorption test

The major goal of this research is to turn the water hyacinth plant's biological waste into a profitable commercial product with increased mechanical strength. Due to the hydrophilic nature of the fibres, the hyacinth composite sample initially absorbs relatively little water. However, continuous monitoring results showed that after a specific amount of time, the samples reach consistent weight.

3.4 Tensile strength

Table 2 explains how samples of natural fibres from water hyacinths were selected at various lengths. When compared to other natural fibres, this tensile strength is average. However, there is no significant change in the tensile strength. Water hyacinth single fibre has an average tensile strength of 26.43 N and a maximum deflection of 28.94%.

Table 2. Tensile strength of a single fibre from an extracted water hyacinth plant.

Different types of extraction method	single fiber tensile strength (Mpa)
Retting process	2.6
Manual extraction	2.13
Mechanical extraction	3.18
Hot water boiling	2.22

chemical extraction method	2.134

3.5 Dynamic Flexural Modulus

Figure 6 demonstrates that as a result of the water hyacinth percentage, MOE values considerably rose. This result is brought about by the ultrasonic waves' propagation through the composite, which is influenced by the material's stiffness and density. The density of the sample value was taken into consideration in these analyses (Sylvatest Duo technique), in order to be more accurate. A similar outcome was attained using different samples.

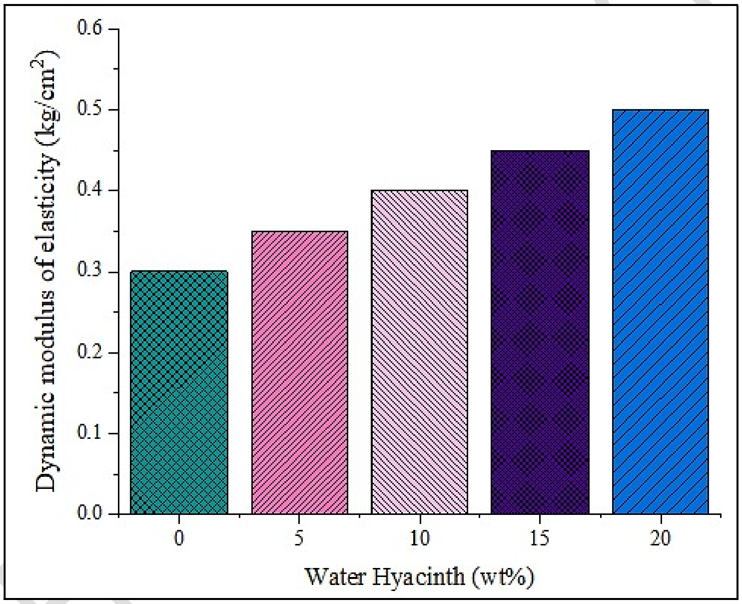


Figure 6. Composites made of polyester resin and water hyacinth have a dynamic modulus of elasticity.

Figure 7 displays the results of static MOE for composites having 5, 10, 15, and 20 wt% water hyacinth fibre. The MOE values increased and the elastic modulus fell as the composite's density rose, which could have been a result of a water hyacinth-polyester interfacial separation brought on by the fiber's ineffective interaction with the polyester matrix.

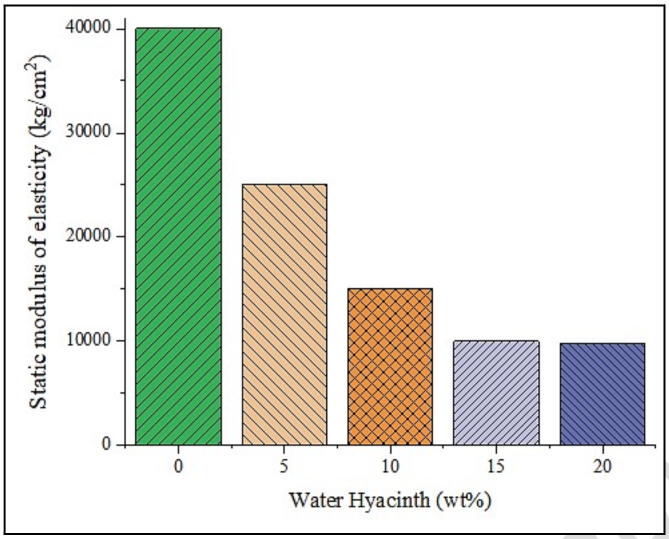


Figure 7. Composites' static modulus of elasticity.

Figure 8 depicts the MOR. The composite with the lowest MOR readings from it had a 20 weight percent water hyacinth fibre content. Evidently, the incompatibility between polyester resin and fibre led to a more brittle substance.

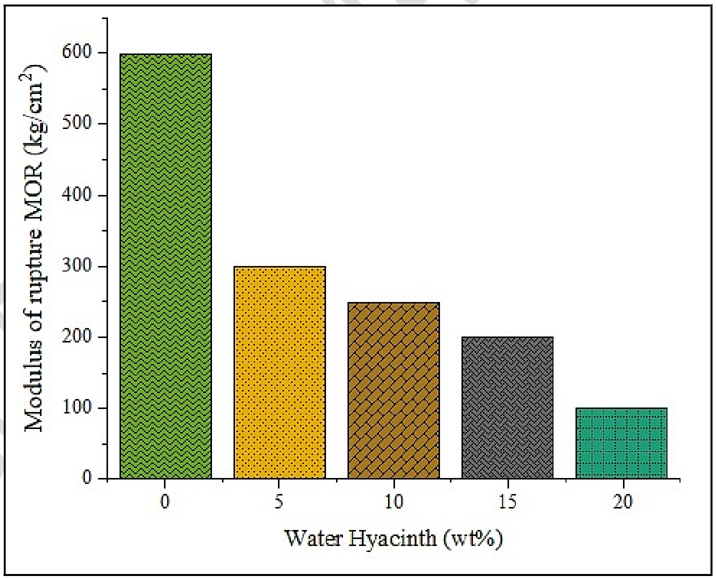


Figure 8. Composites with varying amounts of water hyacinth fibre have a modulus of rupture.

3.6 Compression Strength Parallel

Figure 9 shows the parallel compression strength effort values that decreased with increasing water hyacinth concentration. These results are comparable to those from composites made of pure wood (325-700 kg/cm2) and wood-epoxy resin (238-496 kg/cm2).

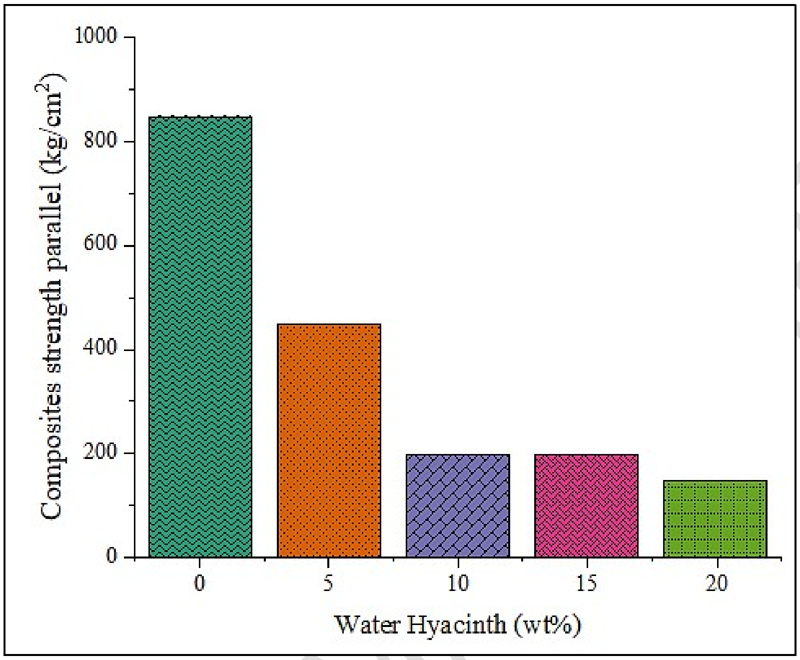


Figure 9. Comparative compression strength of composites made of polyester resin and water hyacinth.

3.7 Biological analysis

Eichhornia crassipes, sometimes known as the water hyacinth plant, was first found in Tamil Nadu, in southern India. Particularly in the Tiruchirappalli region, the bulk of the ponds, lakes, and other bodies of water are covered with hyacinth plants. The hyacinth plant is first picked near bodies of water. The plant is then divided into its component pieces.Fiber is produced from the water hyacinth plant stem. This hyacinth plant frequently has spongy leaves, purple blossoms, and a stem that is between two and three metres long. In this work, a brand-new mechanical extraction technique is used to separate hyacinth fibre from the stem of the parent plant. The quantity of fibre is enhanced while the trash is decreased by up to 80% when fibre is extracted mechanically. The original fibre length of the plant stem is removed with the aid of this equipment. Prior to this, all labour was done by hand or by retting natural fibres like hyacinth plants.

3.8 Thermo gravimetric analysis

In this study, the heat degradation of hyacinth fiber composite was investigated with a focus on understanding its thermal behavior at various temperature stages. The findings revealed distinct phases of degradation corresponding to specific temperature ranges. Initially, at 92°C, the hemicellulose component of the water hyacinth fiber began to disintegrate, marking the onset of the first degradation phase. Subsequently, at 214°C, the cellulose component initiated a second phase of heat breakdown. These temperature thresholds indicate critical points where structural components of the hyacinth fibers start to break down under heat stress. The composite material exhibited thermal degradation percentages of 45% and 36.5% in the first and second phases, respectively, suggesting significant changes in its physical and mechanical properties with increasing temperature. Moreover, observations beyond 600°C indicated the presence of complex lignin structures within the fiber composites, characterized by aromatic rings, which contributed to prolonged thermal stability. Overall, these findings contribute to a better understanding of how hyacinth fiber composites respond to heat, offering insights that can inform their application and processing in various industrial and environmental contexts.

5.1 Morphological analysis

5.1.1 Infrared spectroscopy using the Fourier transform and the X-ray diffraction method

Traditionally, this technique is used to distinguish between the material's crystalline and amorphous phases. Figure 10(a) uses a sharp curve of diffraction patterns to show the cellulose content of hyacinth fibre. The water hyacinth fibre composite's FTIR spectra, with a wavenumber of 4000-500 cm-1, is shown in Figure 10(b).

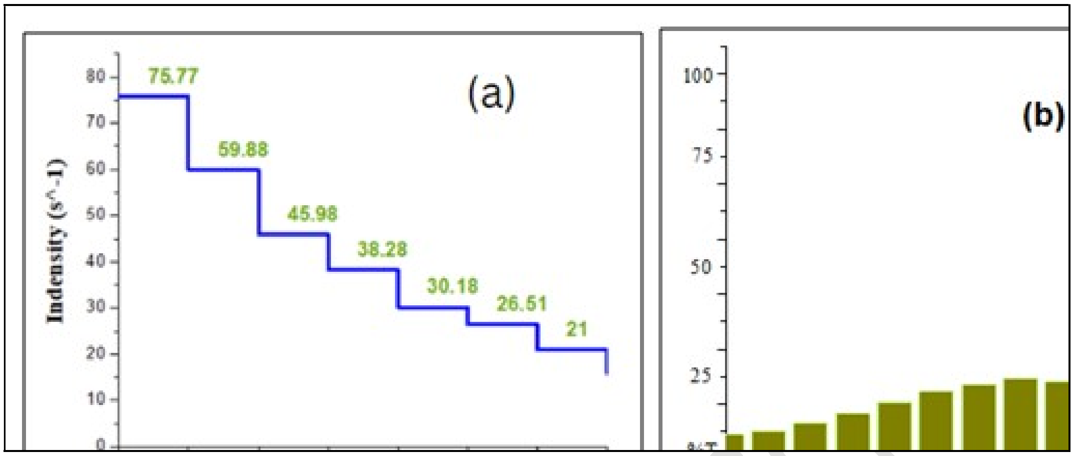


Figure 10. (a) XRD, (b) FTIR Spectrum of WH composite

5.1.2 Scanning electron microscope

Using a MIRA3 TESCAN microscope with a 1.03 mm view field and a maximum magnification of 1000, SEM is used to study the surfaces formed by composites made of water hyacinth fibres. Unfinished water hyacinth plant fiber-reinforced composite samples are shown in Figure 11 as SEM pictures.

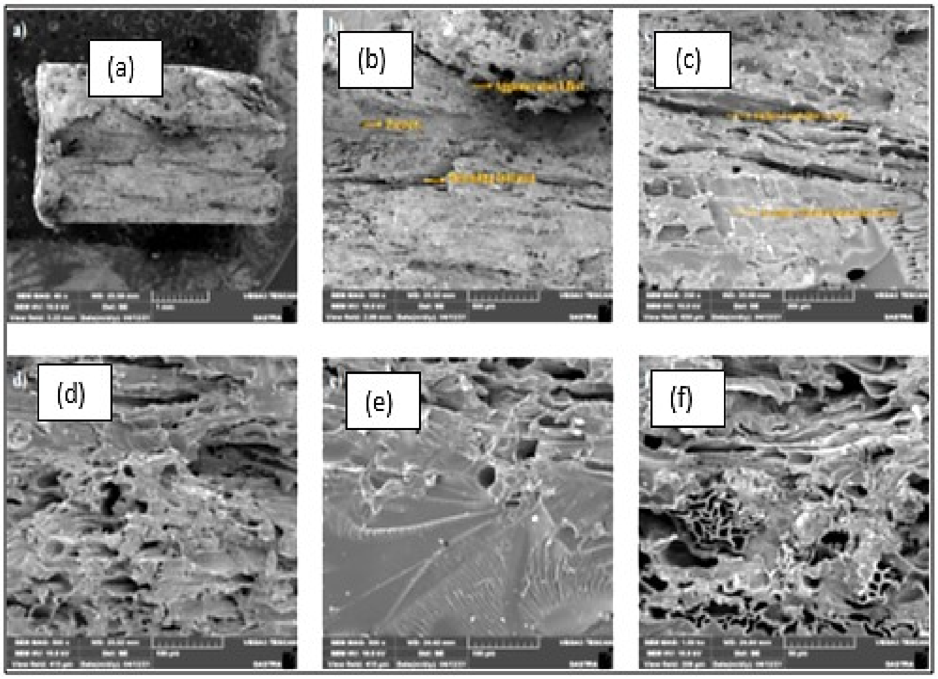


Figure 11. (a–f) WH natural fibre composite SEM pictures

5.1.3 EDX Analysis

The EDX and elemental analyses of composites made of water hyacinth are shown in Figure 12. The compositional constituents in composites, such as carbon and oxygen, are shown in this graphic along with a few other elements. The fibre is combined directly with a matrix component to remove from the parent plant without being washed or chemically treated. This is primarily the cause of the magnesium, silicon, calcium, and sulphur elements' extremely low concentrations. If the fibre is well cleaned before the matrix material is mixed, this small amount of additional elements did not show.

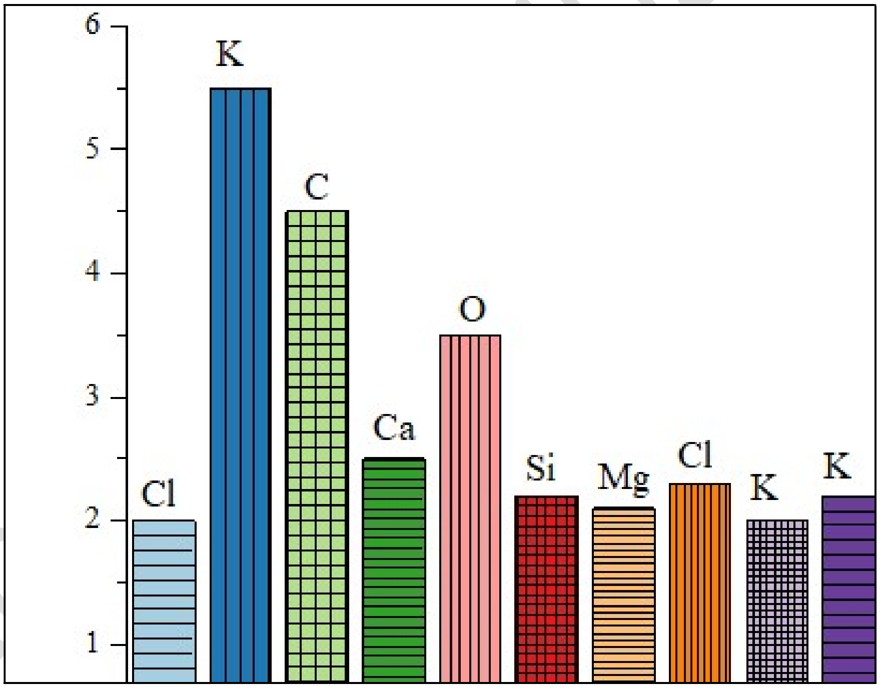


Figure 12. Water hyacinth plant composite EDX analysis.

6. Conclusion

This article shows how thermosetting resins and water hyacinth fibre may be combined to create high-performance bio-composite materials that have the potential to reduce environmental impact and dependency on non-renewable resources. The study highlights how crucial innovation in materials science is to achieving environmental sustainability objectives. A proactive approach to resource management and environmental stewardship is demonstrated by the integration of thermosetting resins with water hyacinth fibre, opening the door to more robust and environment-friendly material solutions. In this paper, the morphological, physical, and mechanical characteristics of a composite made of water hyacinth (Eichhornia crassipes) are examined. By incorporating water hyacinth fibres into polymer composites, it was possible to create composites that were lighter and provided better acoustic insulation than polyester resin.

1. The hyacinth plant fibres are efficiently removed using a mechanically constructed manual extraction equipment. This mechanical-based extraction technique has increased its efficiency by 80% when compared to the other extraction techniques (retting, hot water boiling, and manual extraction).
2. The fibre should have a very high cellulose content and a very low hemicellulose percentage in order to better reinforce the matrix material and provide a very high mechanical strength for the composite.
3. The elemental mapping result indicates that the primary components of the water hyacinth natural fibre composite are carbon and oxygen.
4. Microscopy is used to identify some of the contaminants. The composite has a density of 1.15 g/cc while the fibre has a density of 1.33 g/cc.
5. Adding water hyacinth fibres to a polyester resin allowed for the creation of composite materials that were lighter and provided better acoustic insulation than the polyester resin alone.
6. The crystallinity index indicates the degree of ordered molecular structure in the composite, which affects mechanical strength and thermal stability. Higher crystallinity often correlates with improved tensile strength and rigidity. Heat

degradation, however, can reduce the composite's performance by causing loss of structural integrity and weakening fiber-resin bonds, impacting durability and overall functionality

Competing interests

The authors declare that they have no competing interests.

Consent for publication

Not applicable

Ethics approval and consent to participate

Not applicable

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Authors' contribution

Author A supports to find materials and results part in this manuscript. Author B helps to develop literature part.

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