

## PRODUCTION OF CELLULOSE FROM INVASIVE SPECIES (WATER HYACINTH): A SUSTAINABLE SOLUTION FOR ENVIRONMENTAL AND ECONOMIC CHALLENGES IN SRI LANKA

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**ABSTRACT:** Water hyacinth (*Eichhornia crassipes*), an invasive aquatic weed, poses significant environmental, economic, and social challenges in many tropical regions, including Sri Lanka. However, its high cellulose content and low lignin composition make it a promising non-wood biomass for sustainable cellulose extraction. This study aimed to develop and evaluate an efficient chemical method for extracting cellulose from water hyacinth. The stems were subjected to bleaching with sodium hypochlorite at different residence times (2, 6, 8, and 10 hours), followed by alkaline treatment using sodium hydroxide. The cellulose yield was measured concerning the initial dry biomass, with the highest yield of 36.08% obtained at a bleaching duration of 10 hours. The color change from brown to white indicated progressive delignification. Fourier-transform infrared spectroscopy analysis confirmed cellulose enrichment, as indicated by the disappearance of hemicellulose- and lignin-associated peaks and the predominance of O–H, C–H, and C–O–C stretching vibrations typical of pure cellulose. The results demonstrate that water hyacinth can serve as a viable alternative cellulose source, with yields comparable to or higher than traditional non-wood feedstocks such as rice straw and bagasse. This process supports the circular economy by converting waste biomass into high value materials, reducing dependence on imported cellulose and promoting resource efficiency.

*Keywords:* cellulose extraction, bleaching, water hyacinth, circular economy

### 1 INTRODUCTION

Water Hyacinth (*Eichhornia crassipes*) is an aquatic weed species that grows rapidly and covers the entire water surface with a thick covering. This plant is also called “Japan Jabara” in Sri Lanka. The high-density growth of water hyacinth, primarily driven by eutrophication in open water bodies, leads to significant ecological, operational, and social challenges. It clogs irrigation canals and hydropower systems, restricts livestock access to water, obstructs rivers and navigation routes, and displaces native aquatic vegetation. The dense cover alters essential water parameters such as pH, temperature, and dissolved oxygen while severely limiting sunlight penetration, which in turn degrades water quality and aquatic life. Beyond environmental and economic concerns, the plant contributes to public health issues by creating breeding grounds for disease-carrying vectors like mosquitoes and snails, which spread illnesses such as dengue and malaria. Socially, water hyacinth hampers livelihoods dependent on water transport, fishing, and farming, while also diminishing the aesthetic and recreational value of affected water bodies (Nandiyanto et al., 2023).

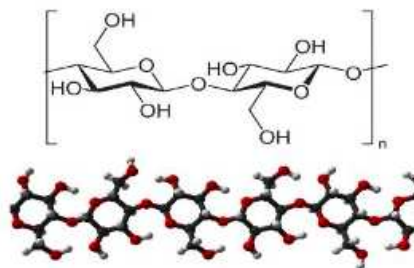
Controlling water hyacinths includes chemical herbicide spraying, biological management with insects and pathogens, and mechanical removal (human cutting, machinery, and obstacles).

Regrowth is inhibited by environmental practices such as lowering nutrient inflows, controlling water levels, and providing shade. Furthermore, circular economy strategies are supported by sustainable applications like biofuel, compost, and handicrafts, which improve the efficacy of integrated management. Despite all these challenges, water hyacinth has biochemical potential, especially as a source of cellulose (Sun et al., 2020). Cellulose is the most abundant organic polymer on Earth and is a basic raw material in paper, textiles, pharmaceuticals, and bioplastics industries. The global demand for cellulose is increasing as the world is moving towards renewable and sustainable materials. Sri Lanka imports most of its cellulose even though there are vast quantities of water hyacinth biomass lying underutilized or discarded after removal. This is an opportunity to turn an environmental liability into an economic asset by producing cellulose from water hyacinth.

Higher concentrations of cellulose are found in materials such as wood, which contains about 40- 50 %, and cotton, which contains up to 90 %. Cellulose is also produced by certain bacteria and algae (Smriti et al., 2023). Figures 1 and 2 show the images of cellulose fiber and cellulose structure, respectively.



**Figure 1.** Image of Cellulose fiber



**Figure 2.** Image of Cellulose structure

Its unique structure gives high tensile strength, chemical stability, and biodegradability, making it essential in many industries. Paper and packaging are the largest consumers of cellulose, followed by textiles, pharmaceuticals, and emerging applications such as nanocellulose for composites and biomedical devices. In Sri Lanka, the demand for cellulose is met through imports, with limited domestic production from wood pulp and agricultural residues. Utilization of water hyacinth as a cellulose source will be a sustainable alternative, reducing the reliance on imported materials and supporting local industries. Traditional cellulose extraction primarily relies on wood pulping techniques such as the Kraft and sulfite processes. While these methods are widely used, they are high-energy and chemical consuming and contribute to environmental pollution due to the release of toxic byproducts. In recent years, there has been growing interest in alternative sources and extraction techniques that are more sustainable and environmentally friendly. Agricultural residues and non-wood biomass, such as salvinia and water hyacinth, have gained attention due to their renewability and lower environmental impact. Water hyacinth contains 45-55% cellulose (on a dry weight basis) and low lignin content, making it suitable for such applications. Recent research has looked into various pretreatment and extraction methods, including alkaline pulping, organic solvent treatment, and enzymatic hydrolysis. Each method

has advantages and disadvantages with regard to cellulose yield, purity, cost, and environmental impact (Magalhães et al., 2023). The main objective of this research is to develop and refine a process to extract cellulose from water hyacinth, to evaluate the yield of the product. By doing so, this research will contribute to sustainable material development, the circular economy, and provide a solution to the water hyacinth problem in Sri Lanka.

## 2 METHODOLOGY

Water hyacinth was collected from a canal adjacent to the Karadiyana garbage dump in Colombo, Sri Lanka. The raw plant material was thoroughly washed with tap water to remove soil and debris, then sun-dried for three to four days. In the laboratory, the roots and leaves were manually separated from the stems using scissors, and the stems were cut into smaller pieces. The stem fragments were oven-dried at 60 °C using a Memmert UN 110 oven and subsequently ground into a fine powder using a domestic blender (Panasonic MX-AC300).

The dried powder was weighed using an analytical balance (KERN ALJ 250-4 AM) to obtain the required quantity. This was mixed with distilled water in a beaker to form a slurry. A 10% (w/w) sodium hypochlorite solution was prepared, and its pH was adjusted to 8 using acetic acid. The powdered water hyacinth material was soaked in the prepared solution at room temperature overnight. Intermittent stirring was carried out using a glass rod for different residence times: 2, 4, 8, and 10 hours.

After soaking, the material was washed thoroughly with distilled water until a neutral pH was achieved and filtered using clean cotton cloth. The delignified material was then treated with 1% sodium hydroxide solution at room temperature for 2 hours under continuous stirring. Following this treatment, the material was again washed with distilled water until the natural pH was restored and filtered through cotton cloth.

A second bleaching step was performed using 5% (w/w) sodium hypochlorite at room temperature for 2 hours. The treated material was thoroughly rinsed with distilled water to remove residual chemicals. The final slurry was filtered using Whatman Grade 4 filter paper and dried under sunlight.

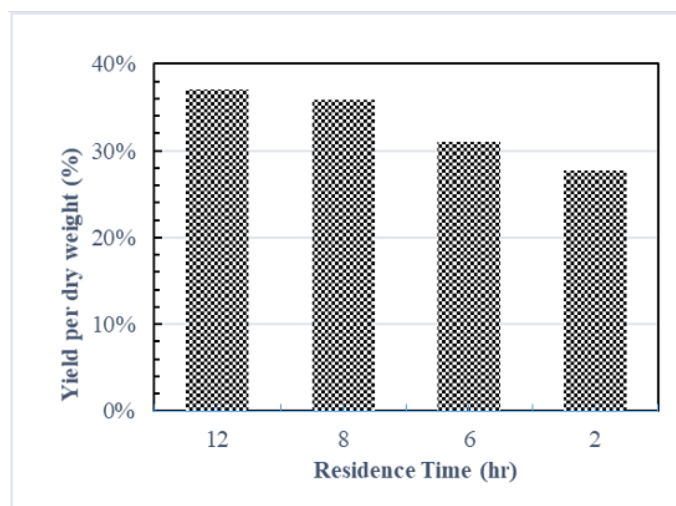
Throughout the entire procedure, the temperature was maintained at room temperature. The pH of the sodium hypochlorite solutions was adjusted to 8 to ensure effective bleaching, as lower pH levels could result in the release of chlorine gas from the solution. The chemical reagents used in this study included sodium hypochlorite solutions at concentrations of 10% and 5% (w/w) for the bleaching steps, and a 1% sodium hydroxide solution for alkaline treatment.

Bleaching effectiveness was investigated by varying the residence time of stirring with sodium hypochlorite solution, ranging from 2 to 10 hours. The alkaline treatment was conducted for a fixed duration of 2 hours. The procedure successfully extracted cellulose from water hyacinth, with observable color changes from brown to white, indicating progressive delignification and bleaching.

### 3 RESULTS AND DISCUSSION

The average cellulose yield was approximately 36% based on the dry weight of the initial water hyacinth biomass for samples subjected to 8–10 hours of bleaching. This yield is comparable to, or even higher than, those reported for other non-wood biomass sources such as rice straw and bagasse (Thongsomboon et al., 2023). The cellulose yield varied according to the bleaching residence time, as illustrated in Figure 3 and Table 1.

It is important to note that both sodium hypochlorite and sodium hydroxide are chemical hazards. Therefore, all experimental procedures were conducted using appropriate personal protective equipment (PPE) and in well-ventilated conditions to minimize risk. Under the conditions described, the reactions were neither explosive nor significantly exothermic, ensuring safe handling throughout the process.



**Figure 3.** Variation of the percentage yield of cellulose per dry weight of water hyacinth with the residence time of the bleaching process

**Table 1.** Effect of bleaching residence time on cellulose yield from water hyacinth

Residence Time (hr)	Dry Weight of water hyacinth (g)	Cellulose Yield (g)	% cellulose yield per water hyacinth dry weight
2	28	7.952	28.40
6	28	8.874	31.69
8	28	10.01	35.75
10	28	10.101	36.08

Fourier-transform infrared spectroscopy (FTIR) analysis was used to assess the extracted cellulose purity by analysing its distinctive absorption peaks and determining if impurity signals are present or absent. Strong O–H, C–H, and C–O–C stretching are observed in pure cellulose at approximately 3300  $\text{cm}^{-1}$ , 2900  $\text{cm}^{-1}$ , and 1050  $\text{cm}^{-1}$ , respectively. While lignin exhibits aromatic peaks close to 1510  $\text{cm}^{-1}$  and 1600  $\text{cm}^{-1}$ , impurities like hemicellulose form a carbonyl peak at 1730  $\text{cm}^{-1}$ . Higher cellulose purity is shown by the decrease or elimination of certain

impurity peaks in spectra compared to those obtained before and after treatment. Thermogravimetric analysis (TGA) is expected to be used to assess the extracted cellulose's purity in future work. With the aid of these analytical methods, the cellulose content can be estimated, and a purity of roughly 90% is predicted based on comparable optimized procedures documented in the literature (Packiam et al., 2022).

Compared with conventional wood pulping, water hyacinth-based cellulose extraction has several advantages, including lower chemical consumption, reduced energy requirements due to softer structure and lower lignin, and the utilization of an otherwise problematic biomass. But challenges remain in terms of seasonal variability in water hyacinth availability, transportation logistics, and market acceptance of non-wood cellulose. Additional processes, such as the generation of biogas from leftover biomass or the extraction of bioactive compounds, could be integrated alongside cellulose production and make the entire system more economically sustainable.

#### 4 CONCLUSION

This study shows that it is feasible to extract cellulose from water hyacinth using sodium hypochlorite and sodium hydroxide through a sequential treatment method. Bleaching time was a key determinant in cellulose yield, with the highest at 36.08% was obtained at a residence time of 10 hours. The color change observed confirmed the samples' delignification and bleaching after treatment. The method was performed at room temperature (non-exothermic and non-explosive) in the presence of adequate PPE and ventilation. Due to the relatively high cellulose content and low lignin fraction, water hyacinth can be considered a feasible source of cellulose in Sri Lanka which is a sustainable alternative to wood. Beyond material production, the initiative also helps control an invasive species that threatens ecosystems and water resources. By implementing such methods, the country would also decrease its reliance on imported cellulose. Future studies should focus on purity analysis and process optimization coupled with value-added products such as nanocellulose or biofuel production to enhance the economic and environmental sustainability of an integrated system.

#### 5 ACKNOWLEDGEMENT

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