Engineered Living Textiles:

Integrating Microalgae into Multilayer Woven Textiles

This study investigates the integration of microalgae into multilayer woven cotton–hydrogel textiles as an engineered living material for carbon capture. The study focuses on how material design, processing conditions, and immobilisation strategies influence microalgal viability and CO_2 sequestration, with the aim of developing a biocomposite that can compete with conventional cultivation methods while enabling carbon capture in everyday urban environments.

Through extensive technical characterisation, key material and process variables were systematically tested to determine an optimal configuration for supporting microalgal viability and function. This included evaluation of textile architecture, hydrogel incorporation, moisture retention behaviour, and cross-linking methods, all assessed in relation to biological performance and material stability. Results show that microalgae can be successfully immobilised within both plain cotton and multilayer cotton–hydrogel textiles. Moisture retention was identified as a critical factor: plain cotton structures dry out rapidly, leading to reduced viability, whereas hydrogel integration within the woven structure forms a supportive matrix that significantly improves moisture retention and enhances microalgal viability. Textile architecture also strongly influences performance, with specific weave structures and material compositions promoting more localised cell attachment and distribution.

The hydrogel component requires cross-linking, which can be achieved through freeze–thawing or freeze-drying. However, these processes negatively affect microalgal viability, particularly under repeated or prolonged exposure. Freezing at -80 °C resulted in the highest post-treatment recovery, while freeze-drying led to reduced performance. Importantly, later experiments demonstrated that introducing microalgae after hydrogel cross-linking avoids exposure to these damaging processing conditions and improves overall system flexibility.

CO_2 measurements did not show consistent net CO_2 uptake. Instead, increases in CO_2 concentration were frequently observed, indicating respiration or reduced metabolic activity under the tested conditions. As such, the current microalgae–textile biocomposite does not yet outperform conventional suspension-based cultivation systems in terms of carbon capture.

Overall, although the material system does not yet function optimally, it demonstrates clear potential as a novel living material. With further optimisation of moisture control, material processing, and system stability, this approach could develop into a scalable cultivation system that can be integrated directly into urban environments while actively contributing to carbon capture.

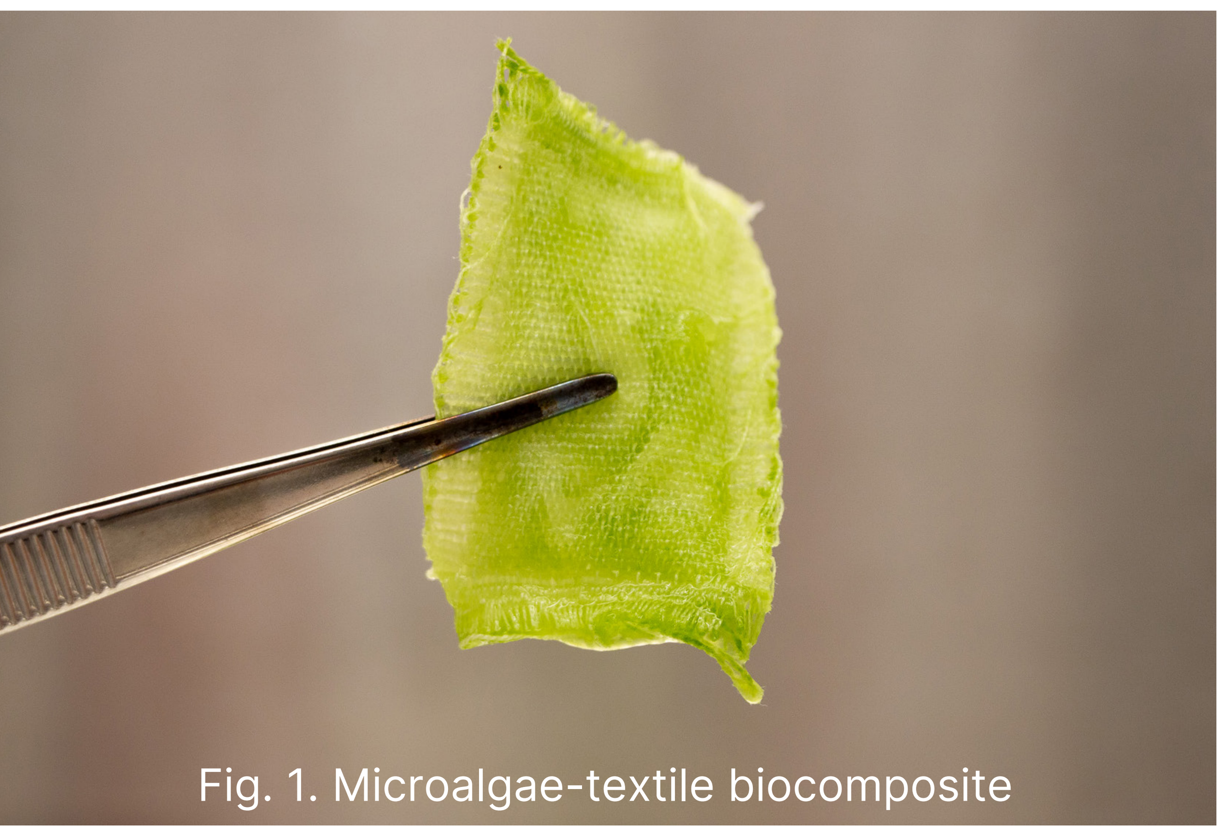
Fig. 1. Microalgae-textile biocomposite


Fig. 2. Microalgae immobilised in textile (microscopy)

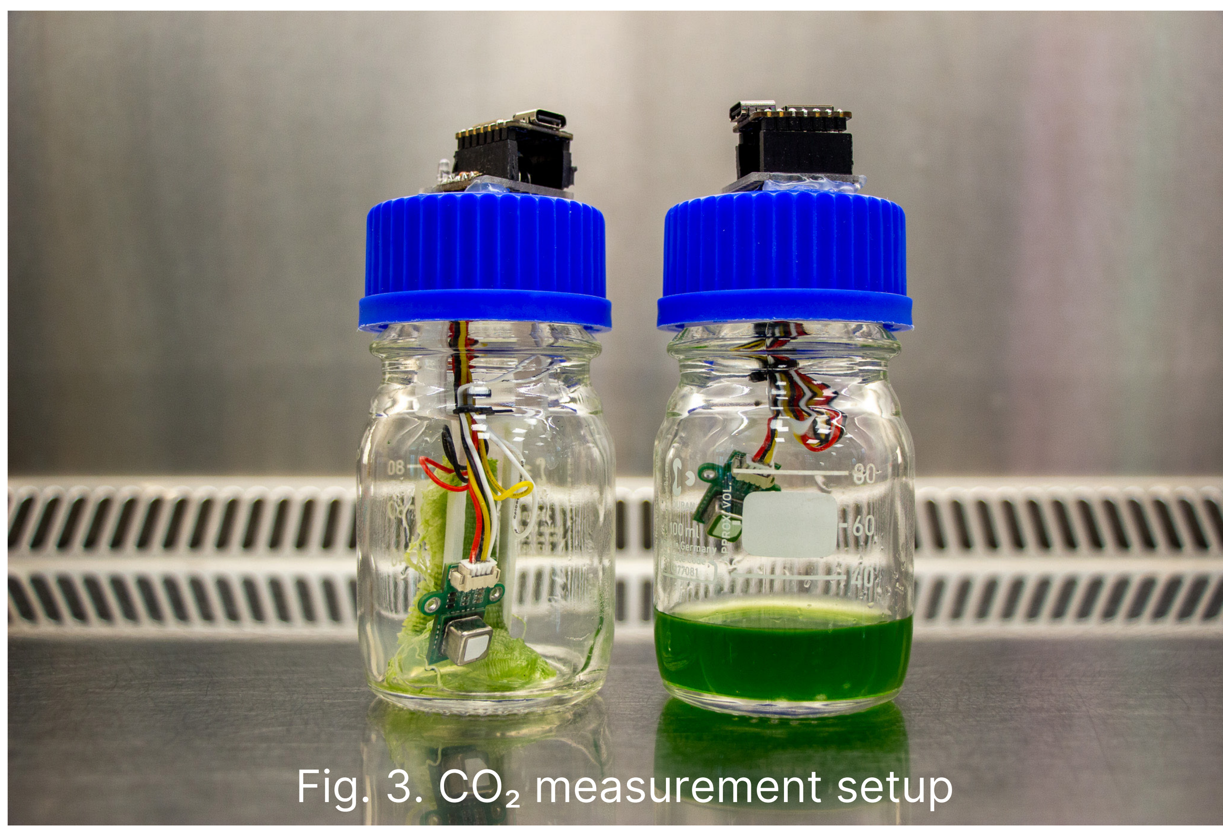
Fig. 3. CO_2 measurement setup

Fig. 4. Microalgae–textile biocomposite sunshade screen (Source: Architect Magazine, UNStudio, Echo, TU Delft)

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May 7th, 2026
Integrated Product Design

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