

Bio-Receptivity of Phytoplankton-Enriched Concrete: A Material that Couples Wastewater Remediation to Carbon Capture and Sequestration

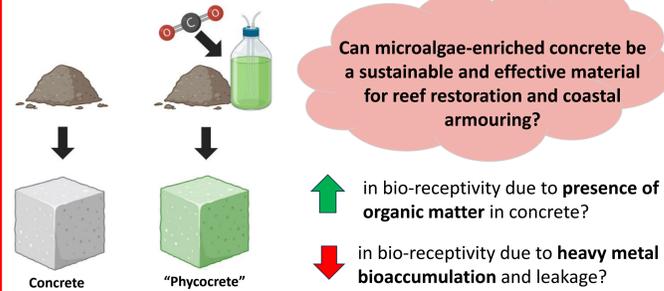
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Background

Concrete is the most commonly used building material in the world and is used for reef restoration and coastal sea walls.

However, concrete production is responsible for 8% of global greenhouse gas emissions (IEA 2017), contributing to the progression of climate change.

Microalgae are small organisms that capture carbon dioxide through photosynthesis. Microalgae grown in nutrient-rich waste can be incorporated into a concrete mix to sequester carbon dioxide in a stable form.



Methods

1 A locally-isolated microalgal strain was grown in media made with 3^o-treated municipal wastewater with aquaculture waste biomass digested by hydrothermal liquefaction (Fish-HTL). The cultures were bubbled with air as a CO₂ source.

2 Microalgae-enriched and standard (control) concrete pucks were cast and submersed in Chester Bay, Nova Scotia, for five weeks. Pucks were removed weekly, and the biofilm growth and health was monitored with reflectance and fluorescence spectroscopy.



Results: Algal Culture Growth

1

The microalgal isolate grew faster in waste-based growth media than in commercially-available synthetic growth media (Fig. 1).

The microalgal isolate had a higher yield (chlorophyll fluorescence as a biomass proxy) in waste-based media than in commercially-available synthetic growth media (Fig. 1).

Waste-based growth medium is more sustainable but also more effective for culturing the local microalgal isolate.

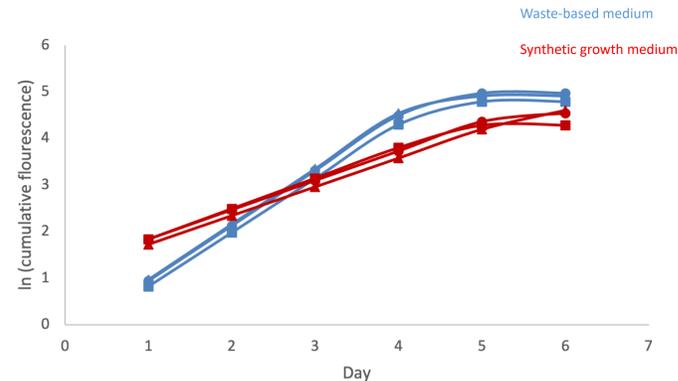


Figure 1. Chlorophyll a fluorescence of algal cultures over time, grown in different media, as a proxy for biomass yield (Ln scale). Waste-based medium contained wastewater and Fish-HTL as a phosphorus source. The synthetic growth medium is a commercially-available growth medium for the algal strain used.

2

Results: Biofilm Formation

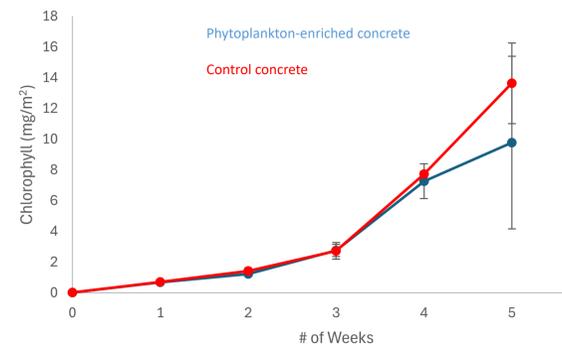


Figure 2. Mean growth of microalgal biofilm (±SD), as the pigment chlorophyll a, on control and phytoplankton-enriched concrete ("Phyconcrete") pucks submersed in Chester Bay, Nova Scotia.

A microalgal biofilm rapidly formed on the surface of the concrete pucks (Figure 2). There was no difference in growth between treatments over the duration of the deployment ($p > 0.05$).

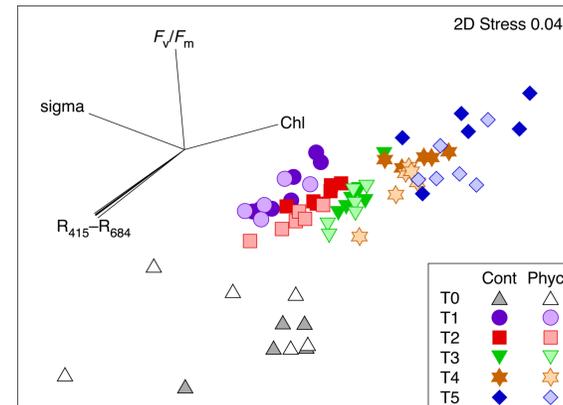


Figure 3. NMDS for two fluorescence parameters (sigma, Fv/Fm) and reflectance measured at 10 wavelengths (415 nm, 441 nm, 486 nm, 494 nm, 525 nm, 576 nm, 619 nm, 636 nm, 670 nm, 684 nm) on phytoplankton-enriched concrete (P) and regular concrete (C) pucks over 5 weeks of biofilm growth (T0-T5).

A non-parametric MDS ordination (Figure 3) is based on chlorophyll concentration, reflectance at 10 wavelengths (colour), and two indices of photosynthetic competence – the maximum quantum yield of PSII (Fv/Fm) and the size of PSII antenna (sigma).

There is a strong trend over time but an overlap in the distribution of control and phytoplankton-enriched samples within each sample period.

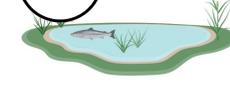
There were significant differences between pucks sampled at different times ($p \leq 0.001$). There were no significant differences ($p = 0.17$) between control and phytoplankton-enriched concrete pucks within each sample period.



Phytoplankton-enriched concrete is just as effective at supporting biofilm growth as regular concrete.

Discussion

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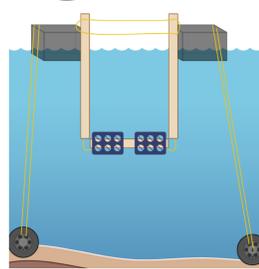


Remediating excess nutrients in municipal wastewater would reduce their discharge into local water bodies.

This could reduce risks of eutrophication on aquatic ecosystems (e.g., coastal hypoxia, harmful algal blooms, habitat loss).

The CO₂ captured during microalgal growth would partially offset the emissions associated with making concrete.

2



Microalgae-enriched concrete can promote the growth of marine organisms, making it a sustainable and effective material for reef restoration and coastal armoring.

Resources

International Energy Agency. 2017. Energy Technology Perspectives 2017. 1-441. https://iea.blob.core.windows.net/assets/a6587f9f-e56c-4b1d-96e4-5a4da78f12fa/Energy_Technology_Perspectives_2017-PDF.pdf



Figures were created using BioRender.



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We honour the passing of Esther Fu, who was a brilliant person and was pivotal in the development of this project. She is deeply missed.