AquaNES

Demonstrating Synergies in Combined Natural and Engineered Processes for Water Treatment Systems

Phosphorus removal and biomass valorisation with an immobilised algae bioreactor (IABR)

1. Challenge

- The EU's Water Framework Directive will lead to **stricter consents for wastewater phosphorus** (P) discharge from 1 to <0.3 mg.L^{-1}.
- Removal of P by conventional treatment is achieved by modified activated sludge for biological nutrient removal (BNR), by coagulation or a combination of both processes. Both are successful at meeting current consents but become less attractive for lower target levels due to **concerns over the robustness of performance delivery** and **excessive use of chemicals and energy.**
- Alternative treatment technologies with a different set of attributes are therefore needed to achieve the very low P discharge, with the combination of natural treatment systems with engineered solutions gaining interest.

2. Applied solution and expected benefits

- **Microalgae** show great potential in the removal of wastewater P in addition to nitrogen (N).
- Implementation of microalgae for P and N removal in either open ponds or closed photo-bioreactors has been limited due to **costly downstream harvesting processes** and **extended treatment times** (days).
- **Immobilised microalgae** in alginate beads (Fig. 1) offers a more viable approach due to ease of harvesting (i.e. gravity settlement) and possibility of **high rate reactors** with **shorter contact times**.

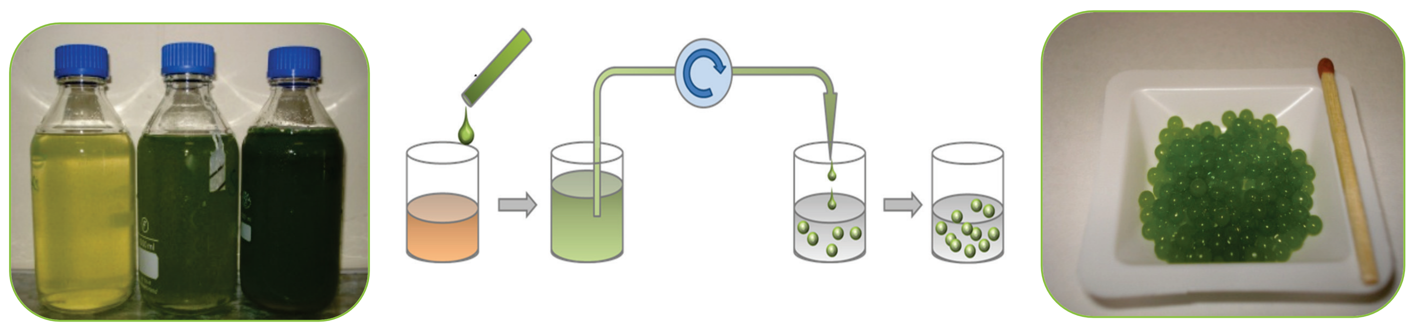


Fig. 1 Algae beads

- Furthermore, algal biomass can be recovered following treatment and **anaerobically digested** for **energy production**.

3. Technical demonstration

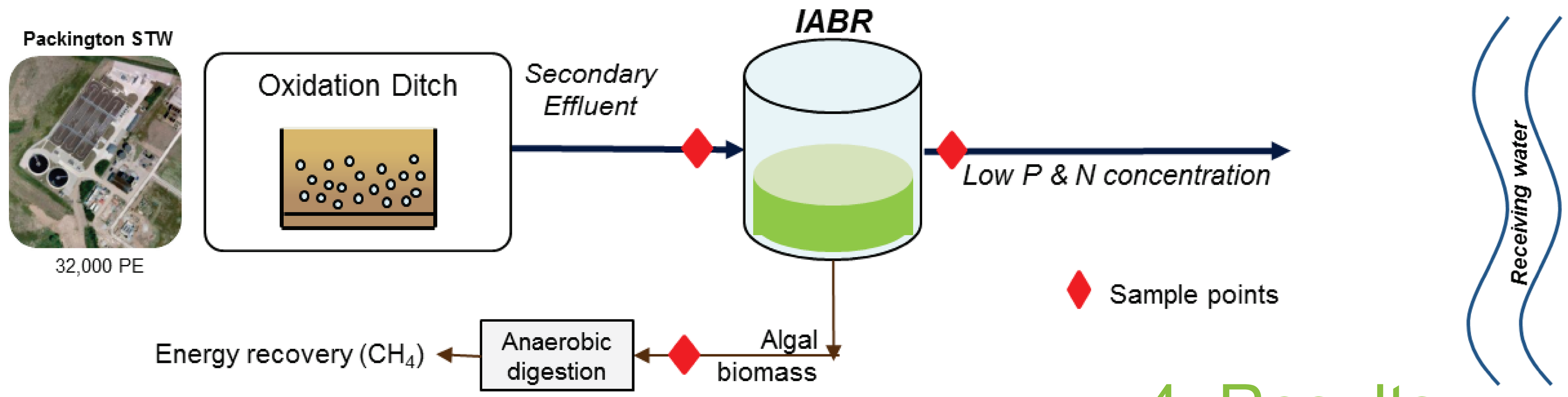


Fig. 2 Demonstration IABR located at Packington STW, UK 5m^3, HRT 12 – 24h

4. Results

4a. Phosphorus removal

- Preliminary IABR lab-scale trials (0.07 m^3) with a 12 h HRT and 10 beads.mL^{-1} achieved **<0.2 mg.L^{-1}** (Fig 3).
- Stable performance maintained for up to 25 days.
- **Challenges** initially encountered with upscaling bead production for the demonstration IABR (5 m^3).

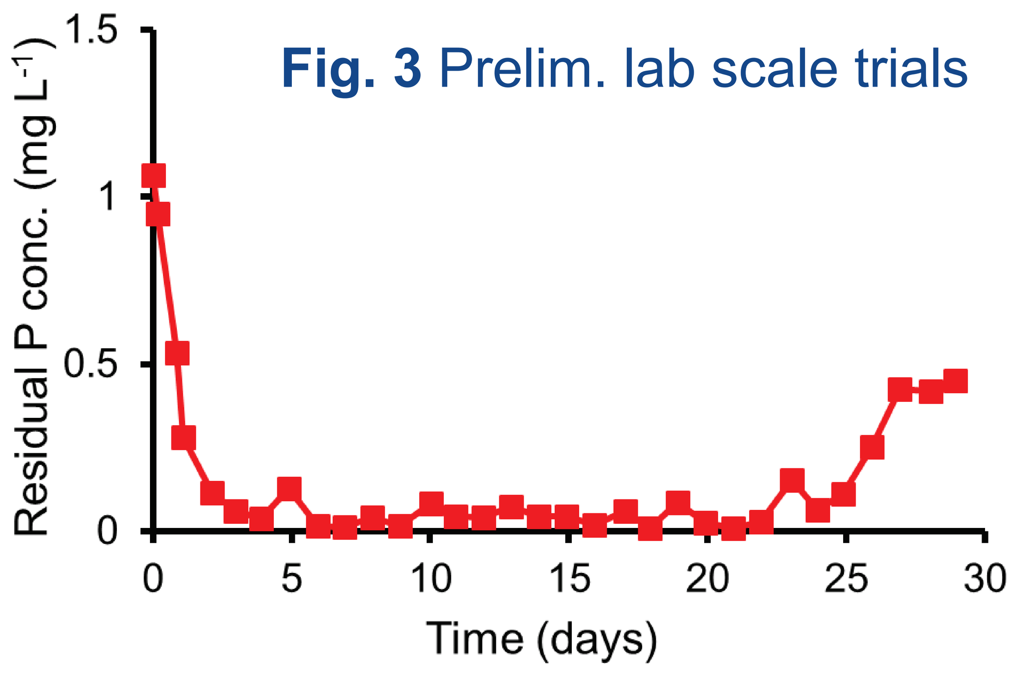


Fig. 3 Prelim. lab scale trials

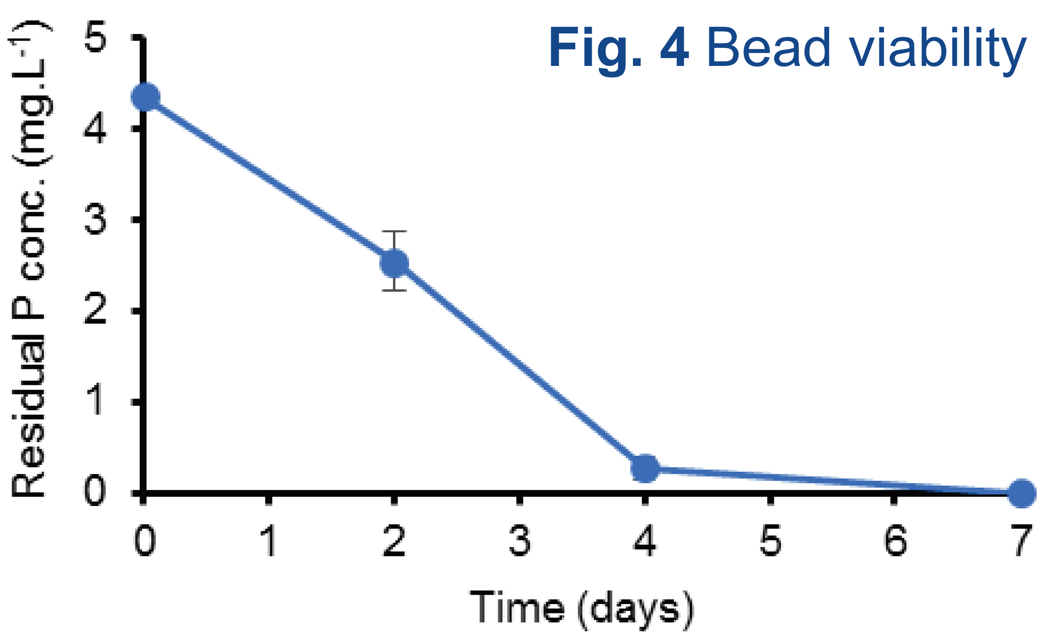


Fig. 4 Bead viability

- Beads produced within bespoke up-scaled production process were found viable during batch lab pre-trials.
- Residual **P <0.2 mg.L^{-1}** achieved within 4 days (Fig. 4).

- When transferred to the demonstration IABR and operated with 5 beads.mL^{-1} a **40% reduction** of P was observed over 7 days to a residual of **0.58 mg.L^{-1}** (Fig. 5).
- **IABR still operational with continued treatment**.
- Areas of further research to improve performance include reactor hydraulics and lighting regime.

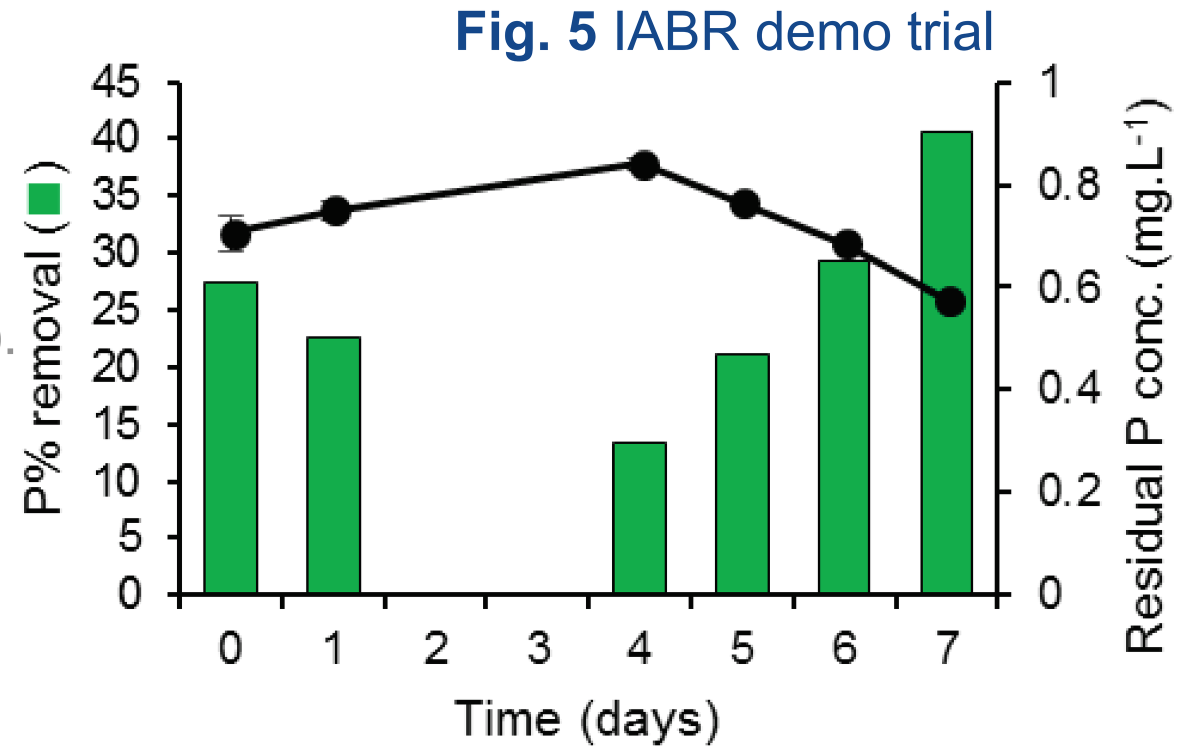
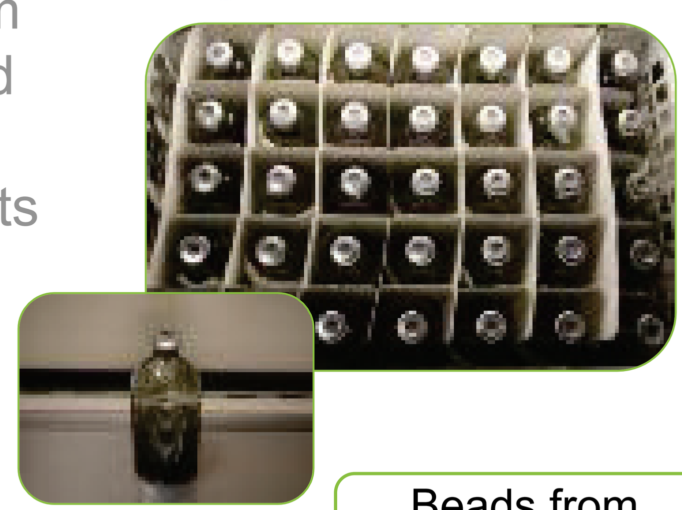


Fig. 5 IABR demo trial

4b. Algal biomass valorisation

Algae beads were recovered from the IABR following treatment, and biomethane yield evaluated through biomethane potential tests (BMT) and compared to control beads (Fig 6).

Fig. 6 BMT tests



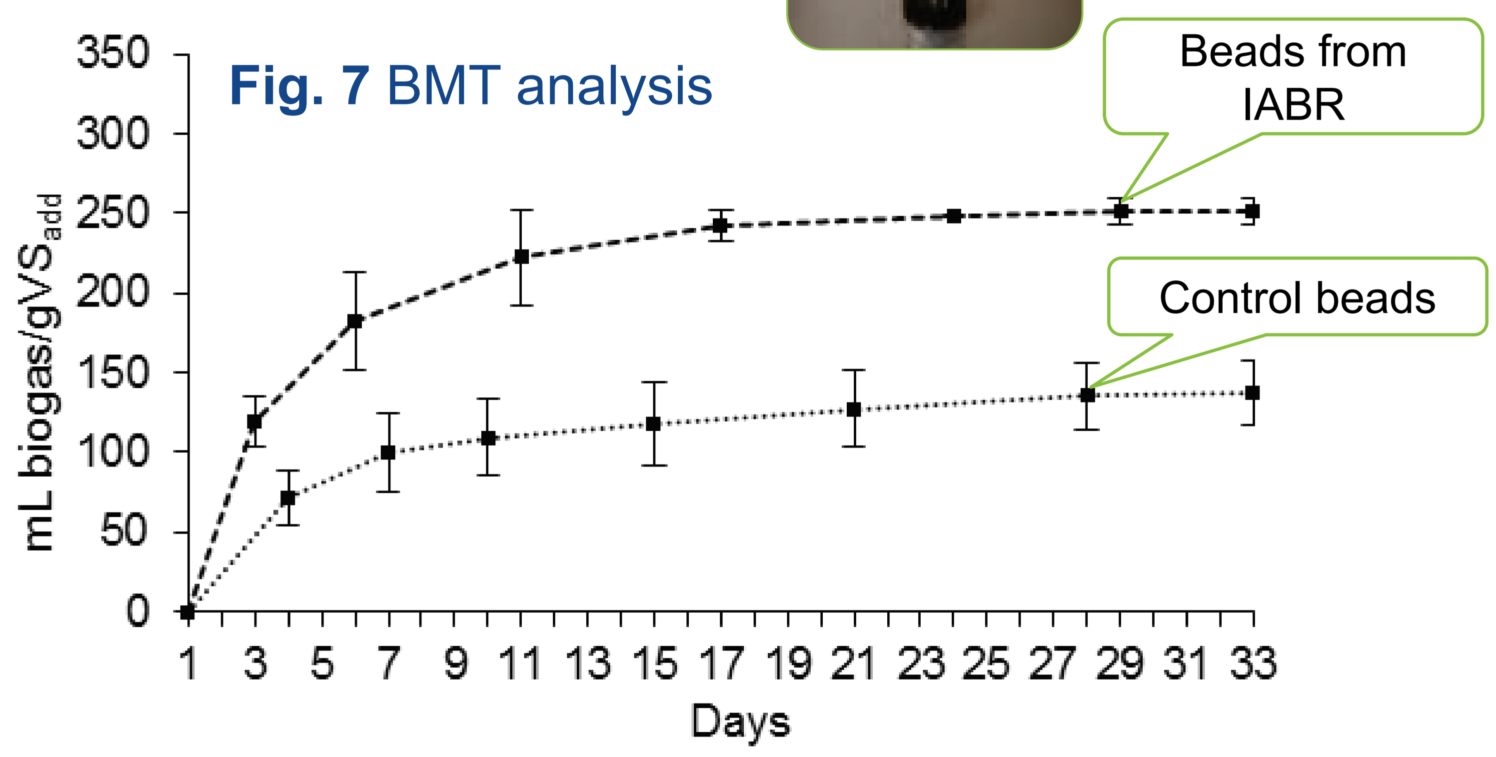


Fig. 7 BMT analysis

- The beads from the IABR exhibited an **enhanced biogas yield** of 251 mL/g/VS$_{add}$ in comparison to the control beads (137 mL/g/VS$_{add}$). (Fig 7).
- Similar biogas yields (265 mL/g/VS$_{add}$) have previously been observed for non-immobilised/suspended microalgae of the same species.
- Biomethane yields of 0.47 and 0.94 CH$_4$ mL/g/VS$_{add}$ were found for the beads used for treatment and the control beads, presumably through increased cell.bead^{-1} concentration through P and N uptake during treatment.
- Could an IABR be an **energy neutral solution** for wastewater phosphorus removal in the future?

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