Microalgae-bacterial granular sludge under reduced aeration efficiently treat coastal aquaculture streams aimed at recirculation

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Introduction

In recent decades, water pollution has become a global issue of increasing environmental concern. In the journey towards the energy and carbon neutrality of wastewater treatment processes, an increasing interest has been placed in microalgal-bacterial granular sludge (MBGS) systems. The combination of both microorganisms within the same granular structure can have several benefits: (i) higher process efficiency due to a more diverse metabolic machinery; (ii) higher sustainability since microalgae can assimilate CO_2 and nutrients to generate O_2, which is in turn used by bacteria for organics oxidation to produce CO_2; (iii) less oxygen supply is needed to treat wastewater [1,2].

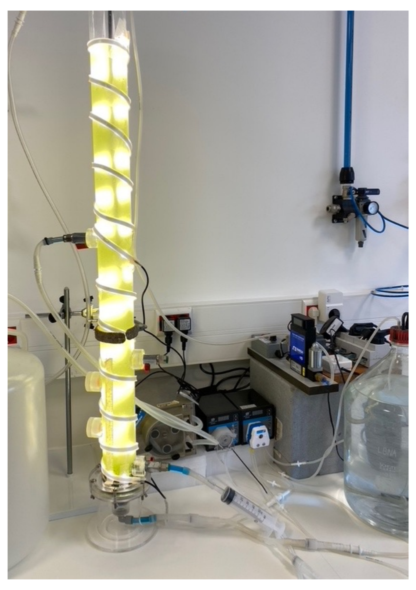
This study investigated the performance of a microalgal-bacterial granular sludge (MBGS) process to treat coastal aquaculture wastewater at different aeration levels to ascertain on the minimum dissolved oxygen content needed to efficiently remove pollutants and allow water recycling in aquaculture facilities.

Methods

MBGS photo-sequencing reactor operation

- Reactor set-up according to previous work [3]
- Quantification of NH_4^+-N, NO_2^--N, NO_3^--N in the wastewater and reactor effluent
- Airflow rate during the aeration period decreased throughout operation:

Phase	Operational days	Airflow rate (L min^{-1})
I	day-0 to -79	3.0
II	day-80 to -106	2.5
III	day-107 to -120	2.0
IV	day-121 to -134	1.5
V	day-135 to -141	1.0



Results

MBGS removal performance

	Concentration (mg L^{-1})					
	NH_4^+-N		NO_2^--N		NO_3^--N	
Phase	WW	Effluent [a]	WW	Effluent [a]	WW	Effluent [a]
I	0.30	0.02 ± 0.03	0.25	1.09 ± 0.71	8.0	2.15 ± 1.45
III		0.00 ± 0.00		2.33 ± 0.38		2.17 ± 0.59
III		0.00 ± 0.00		2.65 ± 0.35		2.10 ± 0.00
IV		0.00 ± 0.00		1.50 ± 0.71		1.15 ± 0.07
V		0.00 ± 0.00		0.35 ± 0.00		0.70 ± 0.00

[a] Mean ± standard deviation

Ammonium

- Complete removal shortly after beginning of operation
- The decrease of the airflow did not impair its oxidation

Nitrite

- Nitrite was not removed and thus released in the effluent
- Lower airflow rates led to lower nitrite levels in the effluent

Nitrate

- Removal fluctuated during phases I-III
- Lower airflow during phases IV-V improved nitrate removal

Lower airflow rates provide sufficient O_2 for:

- ✓ Ammonium oxidation
- ✓ Nitrite and nitrate removal, possibly through denitrification.

Treated water chemical quality and recirculation

- Water quality is determinant for the success of aquaculture production
- NH_4^+, NO_2^- and NO_3^- in the treated effluent were below fish toxicity limits
- The dissolved O_2 and pH values were within the ideal values for reuse
- High-chemical quality treated effluent for water recirculation within a coastal aquaculture farm

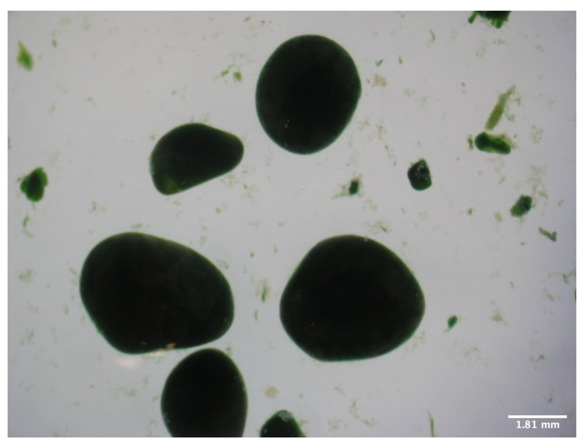
	Reactor effluent (phase IV)	Brackishwater and marine fish toxicity limits or ideal ranges	Reference
NH_4^+-N (mg L^{-1})	0	< 0.3-0.6 [a, b]	[4]
NO_2^--N (mg L^{-1})	< 2.0	< 38.0 [a]	[5]
NO_3^--N (mg L^{-1})	< 1.2	< 10.0 [a]	[6]
DO (mg L^{-1}) [c]	> 5.7	> 5.0	[7]
pH	8.59-8.64	6.5 – 9.0	[8]

[a] LC_{50} values
[b] NH_3-N toxicity limit
[c] DO - Dissolved oxygen

Aeration requirements

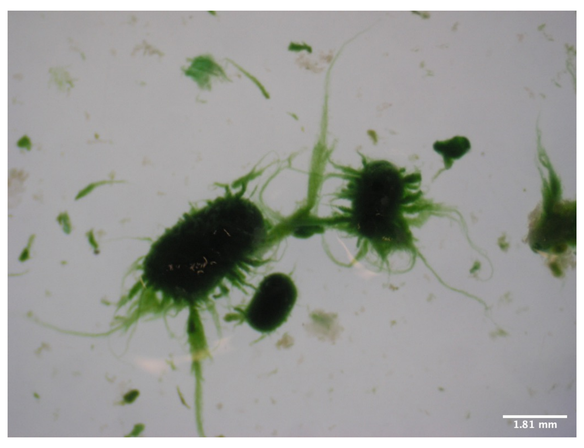
Phase IV

Airflow rate of 1.5 L min^{-1} provides sufficient O_2 to achieve high removal performance and prevent the outgrowth of filamentous organisms



Phase V

Airflow rate of 1.0 L min^{-1} led to the proliferation of filamentous microorganisms that colonized the granules' surface



Conclusions

- The chemical quality of the treated effluents complied with the marine fish toxicity limits for water recirculation
- An extremely low airflow rate of 1.5 L min^{-1} ensured the process removal efficiency and granules' integrity, which represents economic savings for the aquaculture
- Further research and life cycle assessment needs to be conducted to confirm lower operational costs and energy savings of this treatment system
- MBGS is promising as a recirculating aquaculture systems, decreasing the water needs and dependence of land-based aquacultures

Acknowledgements

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