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Evaluation of two different granular sludge reactor configurations for the treatment of freshwater aquaculture streams

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Summary of key findings

Two aerobic distinct granular sludge reactors were operated to treat freshwater aquaculture streams at laboratory-scale: An **Expanded Granular Sludge Bed (EGSB) reactor** operated in continuous mode and an **Aerobic Granular Sludge - Sequencing Batch Reactor (AGS-SBR)** operated as a sequencing batch reactor.

Both units were fed with low ammonium concentrations (2.5 mg N/L). Granular biomass accumulated in both reactors. With the imposed operational conditions, nitrogen removal was of 10 - 20 % and 80 % for the EGSB and AGS-SBR, respectively.

Background and relevance

The aquaculture sector produces more than 50% of the fish consumed worldwide being essential to supply food to a growing world population (OECD/FAO, 2017). Freshwater aquaculture activities require high water supply that might be difficult to access in drought areas and produce polluted effluents that might cause environmental and fish toxicity. For a more sustainable aquaculture, water recirculation is essential. The ammonium removal efficiency is crucial as concentrations higher than 1.5 mg NH_4^+-N/L are toxic for the fish, limiting the water recirculation. Recirculating aquaculture systems (RAS) reduce water usage and improve waste management and nutrient recycling (Martins et al., 2010), boosting aquaculture production. However, RAS have large production costs and increase the water temperature hindering fish health control, especially in warm countries. Therefore, alternative technologies aiming at the reuse of aquaculture streams are needed. Wastewater treatment systems are required to accomplish this good quality water for reuse, which might comprise units based on bacteria, algae and bivalves like in the case of the Aquaval project.

With respect to the biological processes based on bacteria activity, a major challenge when applied to freshwater aquaculture streams is to deal with high wastewater flows containing low concentrations of nutrients (nitrogen compounds). In this line, granular sludge based technologies, where microorganisms grow creating aggregates, can treat high loads due to the high biomass retention and biomass concentrations accumulated. Therefore, this technology allows to operate at relatively short hydraulic retention times (HRT) reducing the implantation area required, which is critical to manage these water loads. AGS has been applied to treat urban and industrial wastewater showing their effectiveness (Gao et al., 2011).

Material and Methods

In this research, two AGS reactors were operated. The feeding media (**Table 1**) was prepared following the concentrations determined from the stream of a trout production aquaculture facility situated in the northwest of Spain (Grupo Tres Mares, Lires, Spain).

The **EGSB reactor** (**Figure 1**) and the **AGS-SBR** (**Figure 2**) **reactor** had working volumes of 2.0 and 2.5 L, respectively. Both reactors were operated at room temperature of 18 - 24 ºC and without pH control. While the EGSB was inoculated with activated sludge from a STP, the AGS-SBR inoculum was collected from a granular reactor in operation in a STP. The EGSB operated in continuous mode and the AGS-SBR in cycles comprising the following successive phases: anaerobic feeding, aeration, settling and decanting. Applied loading rates were 750 mg NH_4^+-N/(L·d) and 12 mg NH_4^+-N/(L·d), respectively.

The pH, temperature, total organic carbon (TOC), chemical oxygen demand (COD), suspended solids, ammonium, nitrite, nitrate and phosphate were evaluated. Moreover, the biomass was characterized in terms of suspended solids, settling properties, density and diameter.

Results

The **EGSB reactor** sludge granulated in less than two weeks improving the settling properties and allowing an upflow velocity (V_{up}) of 11 m/h. The sludge volume index from the inoculum was 191 mL/g VSS and in day 30 was 118 mL/g VSS. The initial granules had a jellyfish aspect, however throughout operation the granule nucleus was filled with biomass. The reactor performed stable for 100 days. The ammonium removal was around 10 - 20% with an ammonium removal rate (ARR) of 120 mg NH_4^+-N/(L·d).

The **AGS-SBR reactor** was gradually adjusted from the high nutrient content domestic wastewater to the low nutrient aquaculture wastewater. The initial granules were round and dark brown about 3 - 4 cm diameter, with an initial settling bed volume of 11 cm. However, throughout operation, granules turned into light brown, diminished in size and a significant amount of biomass was lost (final bed volume 5 cm). The reactor operated through 100 days. The ammonium removal was 92% with an ARR of 11 mg NH_4^+-N/(L·d). All nitrite produced was converted to nitrate.

Discussion

The fast granulation of the **EGSB reactor** allowed to operate at HRT of 5 min which corresponded to V_{up} of 11 m/h**.** The ammonium removal was poor in terms of concentration. Nevertheless, the ARR was competitive achieving 120 mg N-NH_4^+/(L·d). The main observed process was denitrification. Thus, the observed ammonium removal is justified by the heterotrophic bacteria growth. Nitrite concentrations appear in the effluent of the system.

The **AGS-SBR reactor** was able to remove more than 90 % of ammonium even at low C/N ratios. The absence of nitrite in the effluent indicates that this configuration is suitable to apply in aquaculture plants since nitrite is much more toxic to the fishes than ammonium or nitrate.

However, the reactor revealed a significant loss of biomass during operation at the lowest C/N ratio tested. This could be explained by the low availability of carbon source in the medium. Ammonia removal capacity and nitrification capacity did not seem to be affected by this biomass reduction.

Comparing both systems, the EGSB reactor had a ten times higher ARR, being suitable for treating extremely high flows. On the other hand, the AGS-SBR reactor removed about 90 % of ammonium content, thus discharging effluent less toxic for the fishes. The nitrite accumulation in the EGSB reactor is a major drawback if recirculation is aimed. Further studies need to be performed to optimise the operation of both units.

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Tables:

Table 1 - Composition of the synthetic media used to feed the laboratory reactors.

Parameter	Units	Value
pH		6.4 - 6.9
NH_4^+	mg N/L	2.5 - 3
NO_3^-	mg N/L	1.5 - 2.0
TOC	mg C/L	8
PO_4^{3-}	mg/L	0.8

Figures:

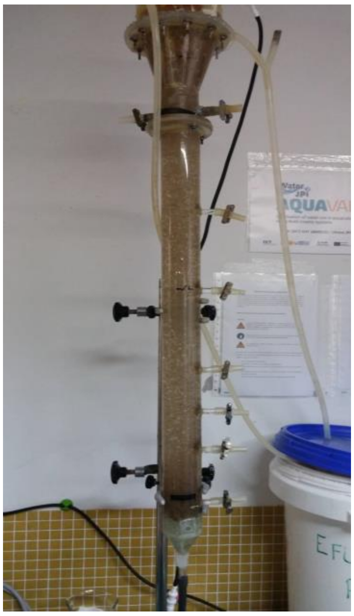

Figure 1. EGSB reactor picture.

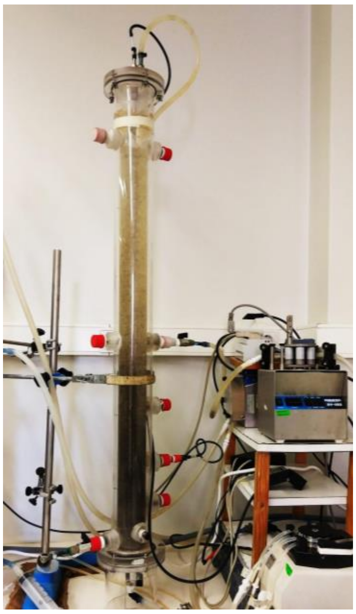

Figure 2. AGS-SBR reactor picture.

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