Bioelectrochemical ammonium removal from recirculating aquaculture system waters

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Recirculating aquaculture systems (RAS) are used for fish cultivation with minimised freshwater consumption. The water recirculating within the system goes through several treatment processes, such as biological filters (**Fig. 1**), to remove *e.g.* toxic ammonia *via* nitrification [1]. The aerated biological filters, however, contribute to the formation of off-flavour compounds (OFCs), such as geosmin, that accumulate in the fish and cause unpalatable taste and odour. Currently, a depuration phase is required where the fish are kept in famine conditions and flushed with large amounts of freshwater, counteracting the earlier water savings and causing the fish to lose up to 50% of their mass [2]. This study examined the possibility to replace the aerated biofilters with anaerobic three-chamber bioelectroconcentration cells (BECs) to remove total ammonia nitrogen (TAN) from RAS waters and mitigate the formation of OFCs.

Materials and methods

- Triplicate three-chamber BECs were used (**Fig. 2**) to remove TAN from RAS waters by concentrating it from the anode into the middle chamber
    - Anode: graphite granules and graphite rods, inoculated with digested sewage sludge and compost
    - Cathode: stainless steel mesh and titanium wire
    - Membranes: CMI-7000 and AMI-7100 (Membranes International, USA) cation- and anion-exchange membranes, respectively
- The aim was to maximise the TAN removal rate using synthetic RAS water, containing 1.55 $mg_{TAN}\ L^{-1}$
- TAN removal was also studied from real RAS water, collected from the RAS facility of the Natural Resources Institute Finland (Laukaa, Finland), containing on average 0.7 ± 0.2 $mg_{TAN}\ L^{-1}$

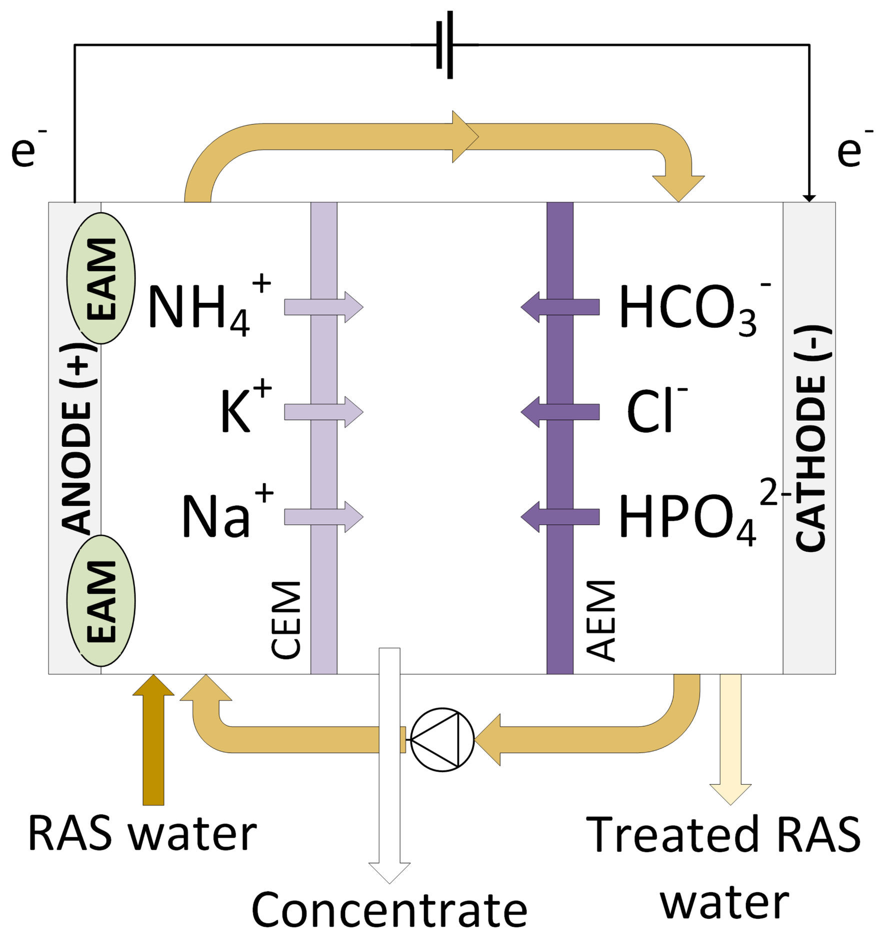

Figure 2. Schematic representation of the anaerobic three-chamber BEC used for TAN removal. EAM = electroactive microorganisms; CEM = cation-exchange membrane; AEM = anion-exchange membrane.

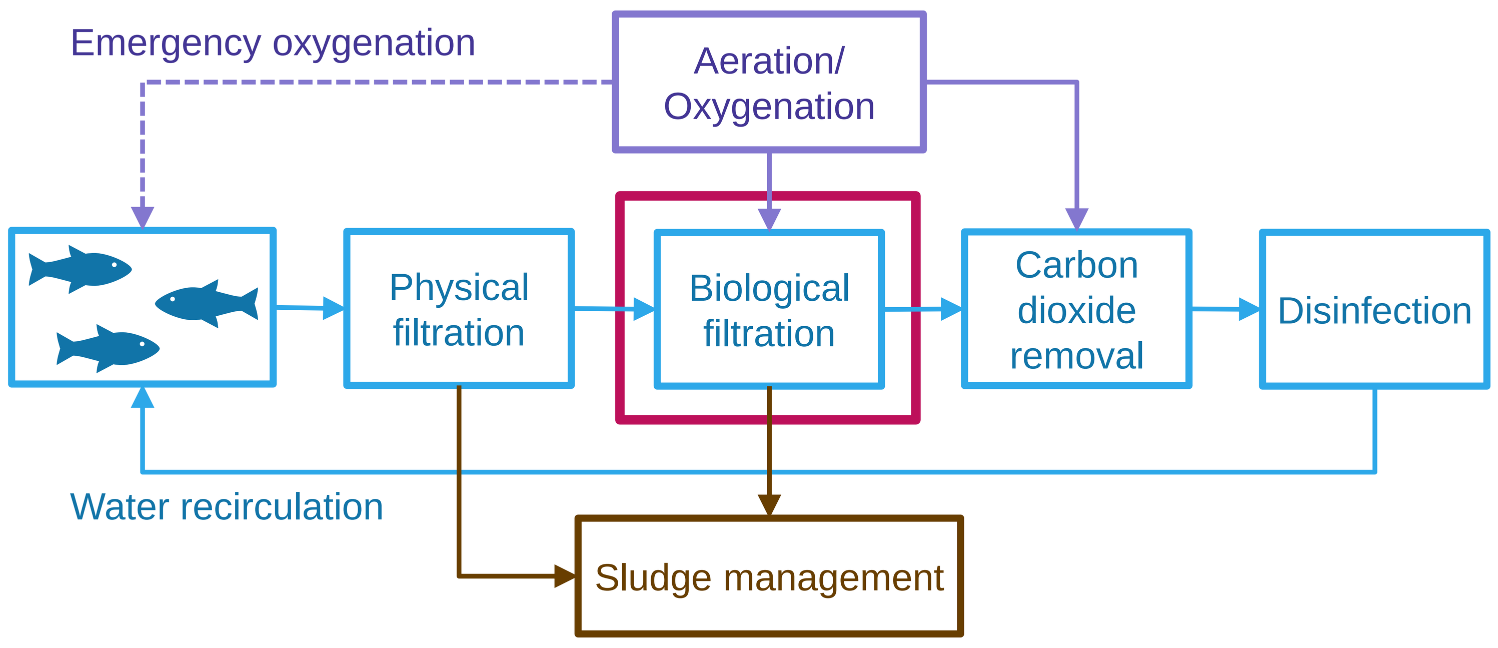

Figure 1. Schematic representation of a typical RAS, depicting the main water (blue), air (purple) and sludge (brown) flows in the system. Adapted from [3, 4]. The biological filtration to be replaced with the BEC is highlighted with red.

Results

- The TAN removal rates obtained with the BEC using synthetic and real RAS water were comparable to the lower end of removal rates observed for biological filters (**Table 1**)

Table 1. TAN removal rates obtained with different reactor types treating RAS waters

Reactor type	TAN removal rate [$g_N\ m^{-3}\ d^{-1}$]
Rotating biological contactor [5,6]	33–138
Trickling filter [5,7]	24–640
BEC – synthetic RAS	28–42
BEC – real RAS	18

- The overall TAN removal efficiencies were high at 96–99% with synthetic and 97% with real RAS water
- Total organic carbon (TOC) removal remained lower at 32–35% with synthetic RAS water

Conclusions

The studied three-chamber BECs were able to reach TAN removal rates comparable to those obtained with biological filters treating RAS waters. The TAN removal efficiencies were high at ≥ 96%. The results suggest BEC could be an alternative for TAN removal in RASs. Further investigation will be focused on the fate of geosmin in the BEC and the possible enrichment of unwanted geosmin-producing microorganisms during longer-term operation, which, according to literature, could be avoided in anaerobic conditions.

References
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