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Forecasting the environmental sustainability of a microalgae raceway pond treating aquaculture wastewater: from pilot plant to system integration at industrial scale

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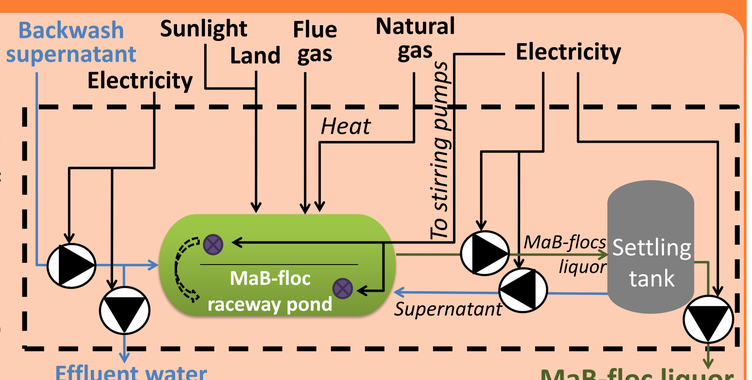
Introduction

Recirculating aquaculture systems (RAS) produce nutrient-rich effluents which need to be treated:

- **Fish sludge:** treatment by anaerobic digestion is an attractive option (Mirzoyan et al., 2010)
- **Backwash water supernatant:** innovative microalgal bacterial floc sequencing batch reactor (**MaB-floc SBR**) technology (Van Den Hende et al., 2014a) is a promising way to avoid costly mechanical aeration of conventional activated sludge systems
  → Harvested MaB-flocs can be valorized as **shrimp feed** or as **biogas** (Van Den Hende et al. 2014b, 2014c)

Switching from linear fish aquaculture and separated aquaculture sludge and wastewater treatment to an integrated MaB-floc-based aquaculture waste treatment system could be a key strategy to mitigate the environmental footprint of the aquaculture sector



Operation principle of a MaB-floc raceway pond with considered input and output

How can the environmental sustainability of existing MaB-floc technology be improved?
How should MaB-flocs be valorized when the technology is implemented in an aquaculture waste treatment system?

Material and methods

1.To study the improvement potential of the MaB-floc SBR raceway pond technology:

- Data collection from a pilot MaB-floc raceway pond (28 m^2) treating backwash supernatant from a pikeperch RAS in Belgium
- Design of 4 up-scaled plants (industrial scale):
  → *L: linear up-scaling (41 ponds; 245 m^2 each)*
  → *S: plant L with propeller pumps replaced by more efficient paddle wheels*
  → *E: plant L with Belgian electricity supply mix replaced by wind power*
  → *M: plant L with a MaB-floc productivity increased by 30%*

Functional unit: production of 1 kg MaB-floc TSS

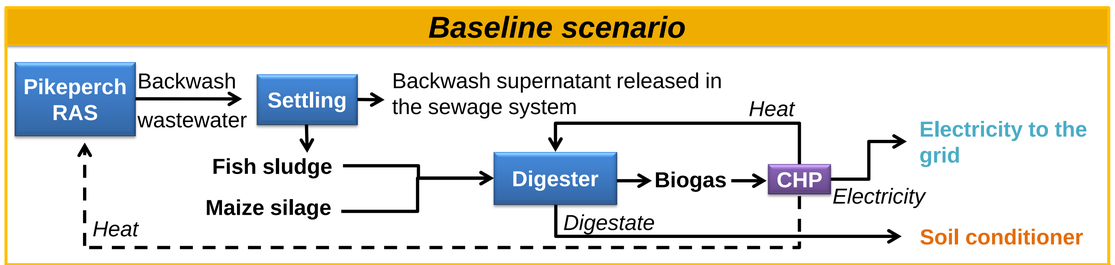
2.To study the valorisation of MaB-flocs in an integrated system

- Definition of 3 integrated scenarios
- Integration of 2 up-scaled plants: L (waste treatment system Up_L) and SEM (combining plants S, E and M: waste treatment system Up_{SEM})

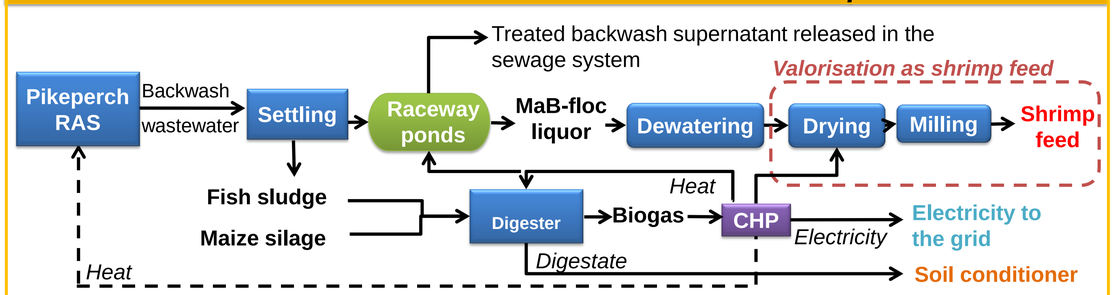
Functional unit: treatment of 1 m^3 of aquaculture backwash water supernatant

→ **Life Cycle Assessment (LCA): freshwater eutrophication potential, carbon and resource footprint** (ISO 14040 and 14044)

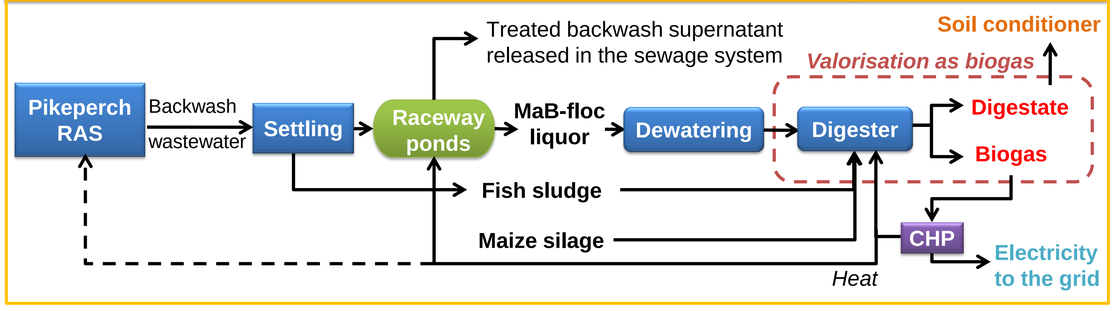
Baseline scenario



Scenario 1 - valorisation of MaB-flocs as shrimp feed



Scenario 2 - valorisation of MaB-flocs as biogas

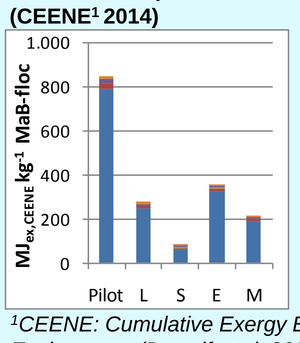


Results

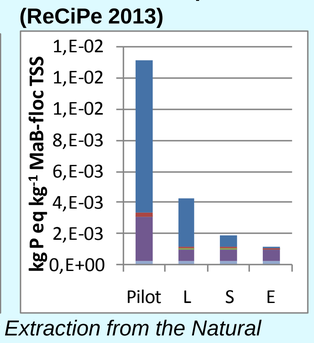
Improvement of the environmental sustainability of the MaB-floc raceway pond

- Pond stirring has the highest contribution in all impact categories
- Up-scaling reduces the resource footprint, carbon footprint and freshwater eutrophication by 66%, 65% and 71%, respectively
- Replacing fossil fuels by wind power reduces the most the environmental impact of the raceway pond, followed by using a more efficient stirring system

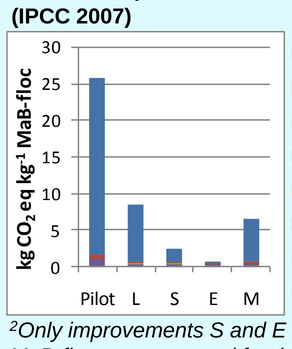
Resource footprint (CEENE[1] 2014)

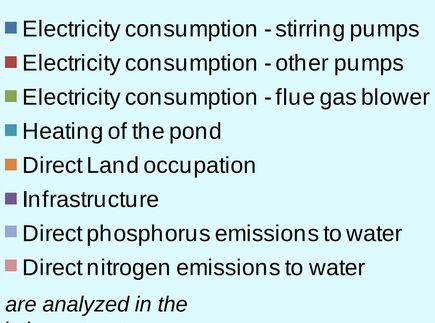


Freshwater eutrophication (ReCiPe 2013)



Carbon footprint (IPCC 2007)





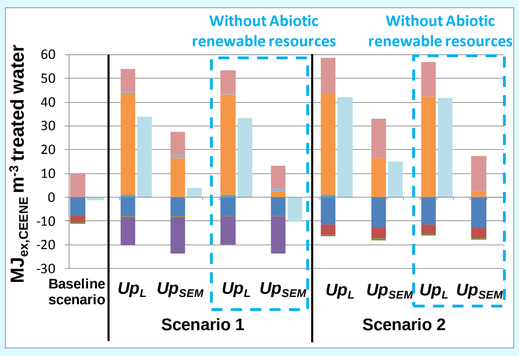
[1]CEENE: Cumulative Exergy Extraction from the Natural Environment (Dewulf et al. 2007)

[2]Only improvements S and E are analyzed in the MaB-floc raceway pond for this impact category

Valorisation of MaB-flocs in the framework of an integrated aquaculture waste treatment system

- Scenario 1 and 2 are only competitive with the baseline scenario if the three improvement options (S, E, M) are implemented
- Valorizing MaB-flocs into shrimp feed is overall a preferable option over biogas from an environmental point of view

Resource footprint (CEENE 2014)



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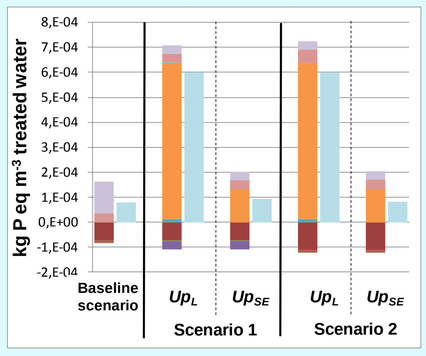

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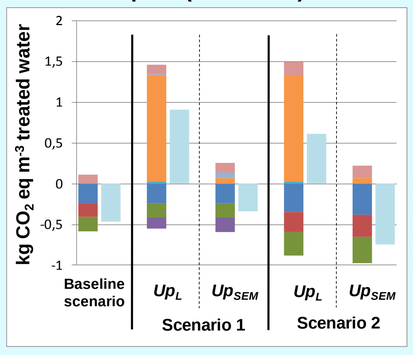

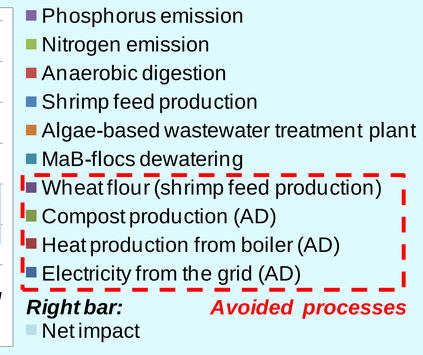

Conclusion and future outlooks

- **The improvement potential of the system is high,** mainly because the energy efficiency of the raceway pond stirring system can be highly improved
- **Valorisation of MaB-flocs as shrimp feed is overall more sustainable than as biogas** from an environmental point of view
- **To improve the energy efficiency** of the raceway pond, more efficient stirring systems should be tested and the pond shape could be optimized
- **To improve the LCA,** GHG emissions from the MaB-floc raceway pond should be measured

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