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Optimization of (hyper) thermophilic blackwater treatment for recovery of biofertilizers and energy

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Motivation

Efforts to address soil deficiencies and improve global food production have resulted in a heavy reliance on mineral fertilizers[1]. Human feces and urine contain essential nutrients such as carbon, nitrogen, phosphorus and potassium which are crucial for plant growth. Fortunately, anaerobic wastewater treatment, which has been traditionally geared toward production of methane, efficiently conserves essential elements in the effluent thereby facilitating nutrient recovery for reuse in agriculture.

Source separated collection of blackwater using (low-flush) vacuum toilets yields a concentrated stream from which nutrients can be more readily extracted. Anaerobic treatment of concentrated blackwater under thermophilic conditions already shows promise for effective COD removal and biogas production [2]. Preliminary experiments have shown that pathogens are also eliminated though the process, enhancing safety of nutrients and biosolids during reuse.

Technological challenge

Thermophilic treatment of blackwater, at 55°C, is a stable process that has been previously pilot tested under the H2020 Run4Life project [3]. Already, COD removal (~70%) and methanization conversions (~60%) comparable to those reported during mesophilic treatment have been achieved while operating at higher organic loading rates (OLRs) and shorter sludge and hydraulic retention times (SRTs and HRTs) [2,4]. Now, along with methane, alternative high-value products, preferably separate CNPK nutrient recovery streams, should be investigated. Furthermore, enhanced hydrolysis should allow for long-term operation at increased loading rates and shorter retention times, without compromising on effluent quality.

Hyper-thermophilic treatment at 70°C, could result in hygienically safe products as well, but at even shorter SRTs. This process however so far, was impeded by unfavorable environmental conditions, i.e., high ammonia levels and volatile fatty acid accumulation [2]. Overall, even though the recovered products may not be risk-free, they need to be risk-mitigated as much as is feasible.

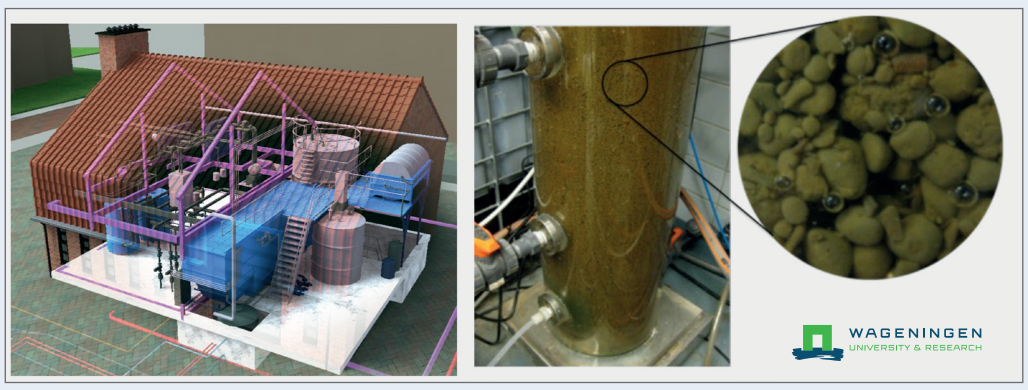

Fig 1. Visualization of the anaerobic blackwater treatment demonstration site at Noorderhoek, Sneek under Run4Life Project (left) and calcium phosphate granulation in lab-scale anaerobic blackwater treatment reactor (right)

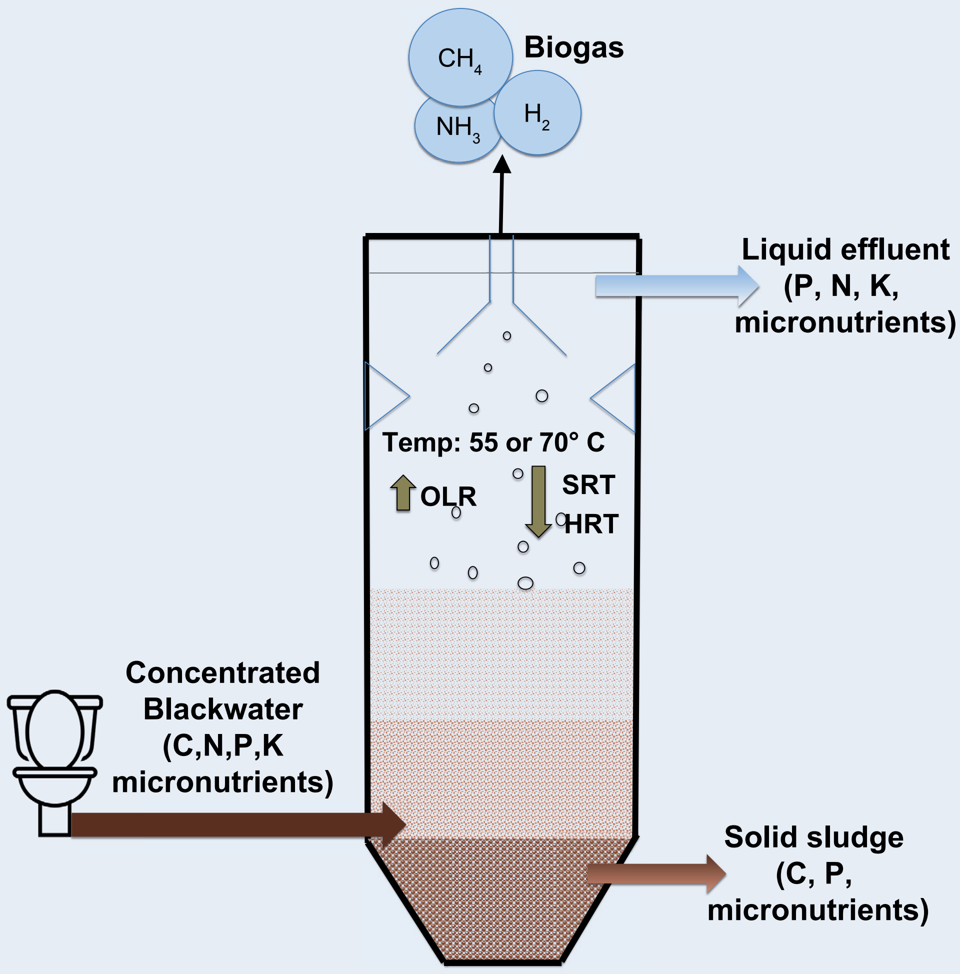

Fig 2. Potential nutrient recovery streams from (hyper)thermophilic anaerobic blackwater treatment

Research goals

Therefore, this project is seeking to optimize the performance of (hyper)thermophilic treatment to maximise the production of reusable recovered products (CNPK, micronutrients, and energy). Specific project objectives are:

- Optimizing (hyper)thermophilic anaerobic reactors for recovery of sludge and nutrients along with energy
- Characterizing (micro)nutrients in concentrated blackwater and their speciation in the reactors
- Developing and testing recovery strategies for CNPK and micronutrients from concentrated blackwater
- Determining the removal efficiency for micropollutants in blackwater through thermophilic anaerobic treatment

References

[1] United Nations Environment Programme (2022) Environmental and health impacts of pesticides and fertilizers and ways to minimize them.
[2] Moerland MJ, Castañares Pérez L, Ruiz Velasco Sobrino ME, et al (2021) Thermophilic (55 °C) and hyper-thermophilic (70 °C) anaerobic digestion as novel treatment technologies for concentrated black water
[3] H2020 Run4Life Project, Source:https://run4life-project.eu/
[4] Cunha, J.R. (2018) Anaerobic calcium phosphate bio granulation

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