D3.3 – Report on design, construction and operation of the Pilot plant 2 (summary)

WP3, T3.3 Design, construction and operation of the Pilot plant 2

[Version 1.1 – 12/11/2024]

Authors: Sarah Moreno Sayavedra (UGent); Lennert Dockx (Aquafin)

Website: walnutproject.eu

Twitter: @walnut_project

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement 101000752.

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Summary

This deliverable (D3.3), part of the WalNUT project and led by Aquafin and UGent, reflects on the integration of **high-rate activated sludge (HRAS)** and **adsorption/ion-exchange (IEX)** into an innovative two-stage system for wastewater treatment and nutrient recovery on **pilot scale**.

In this setup, HRAS served as the first stage, removing organic matter, relying on high organic loading rates and short sludge retention times. The second stage used zeolite-based adsorption to recover nitrogen (N) (ammonium form) as fertiliser. Despite challenges posed by the low nutrient content of raw domestic wastewater, the HRAS process offered notable benefits such as reduced energy consumption, a smaller system footprint through SBR configurations, higher biogas yields, and lower nitrous oxide emissions compared to conventional systems.

The second stage (zeolite column on pilot scale) demonstrated the ability to meet nitrogen discharge limits, producing both solid and liquid bio-based fertilisers (BBFs). The process produced both saturated natural zeolites (with up to 4 g N/kg of zeolites) and regeneration liquid using potassium chloride (KCl) (containing up to 755 mg N/L). However, the low nitrogen concentration in these BBFs limits their economic value. When compared to side stream treatment systems (e.g. N-stripping/scrubbing), the two-stage HRAS-IEX process showed significantly higher costs (up to 57 times more) mainly due to regeneration needs and limited reuse potential of the regenerant. Long-term testing is needed to better understand the durability of the zeolites and to explore options for regenerant reuse to lower operating costs.

Overall, while **the HRAS-IEX system indicates some improvements in comparison to conventional systems**, the low nutrient concentration in recovered products and high recovery costs pose major challenges. These findings suggest that **nutrient recovery from more concentrated waste streams**, such as anaerobic digestion centrate, **may offer more economically viable alternatives**.

Conclusions and Next Steps

Optimal performance of the HRAS process depends on maintaining a high organic loading rate and a short sludge retention time, though this can be challenging with low-strength domestic wastewater. The pilot-scale zeolite adsorption column successfully treated HRAS effluent within required nitrogen discharge limits, but the nutrient content of the resulting fertilisers was relatively low, limiting their economic value. Cost analysis showed that nitrogen recovery using zeolites is significantly more expensive than reference technologies, with regeneration adding further cost and complexity. To improve economic viability and environmental performance, future research should focus on long-term testing with high-strength wastewater (side streams of sludge treatment processes, e.g. digestate), optimising regeneration cycles, exploring reuse of spent regenerant, and identifying more sustainable and local materials, such as coffee grounds, as alternatives to zeolites.

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