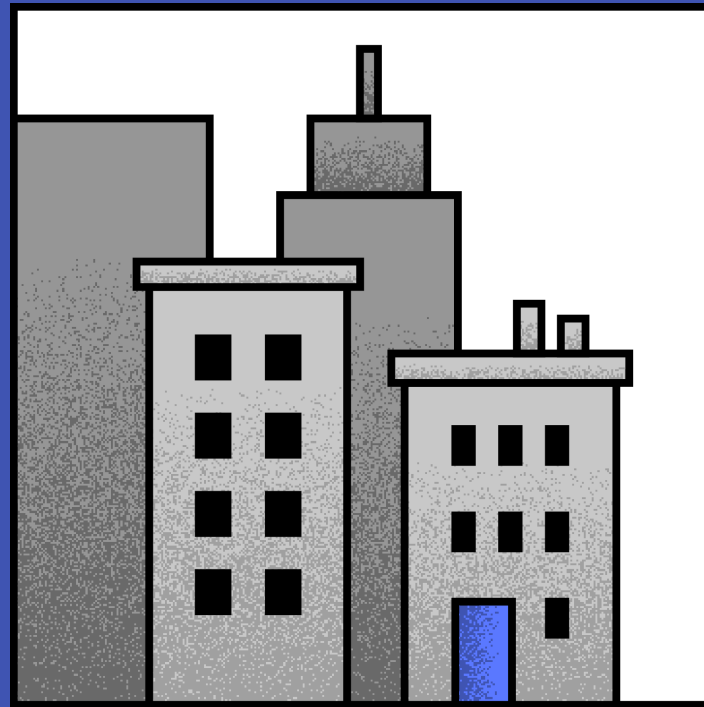


WALNUT



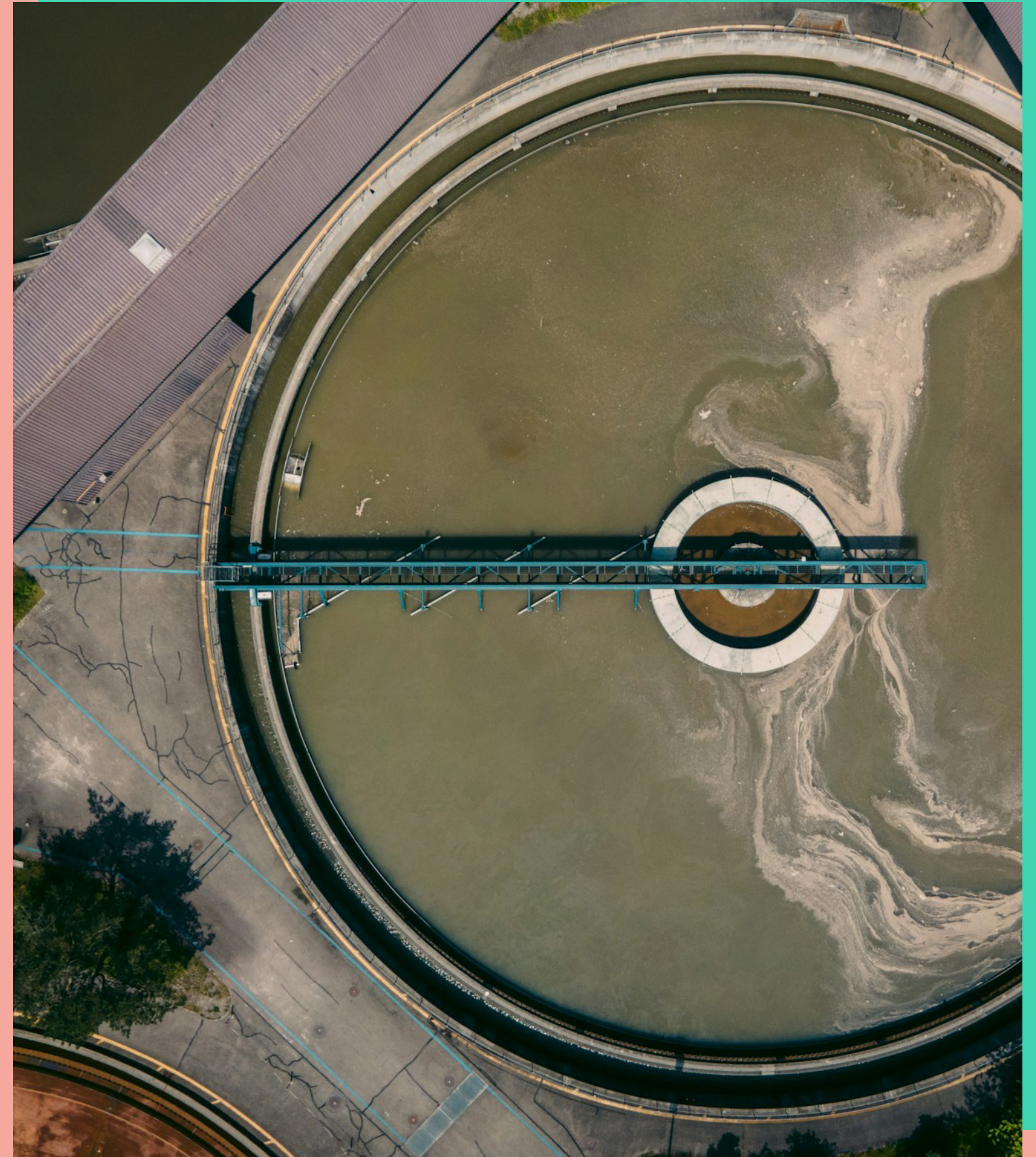
factsheet
URBAN
WW n recovery

Introduction

Nitrogen (N) fixation and production of N-based fertilizers by the application of the Haber-Bosch process is associated with 1-2% of global energy consumption. Additionally, the biological N-removal during urban wastewater (WW) treatment by application of both nitrification (conversion of NH_4^+ to NO_3^-) and denitrification (conversion of NO_3^- to N_2) is an energy demanding process and is moreover linked to additional N_2O emissions.

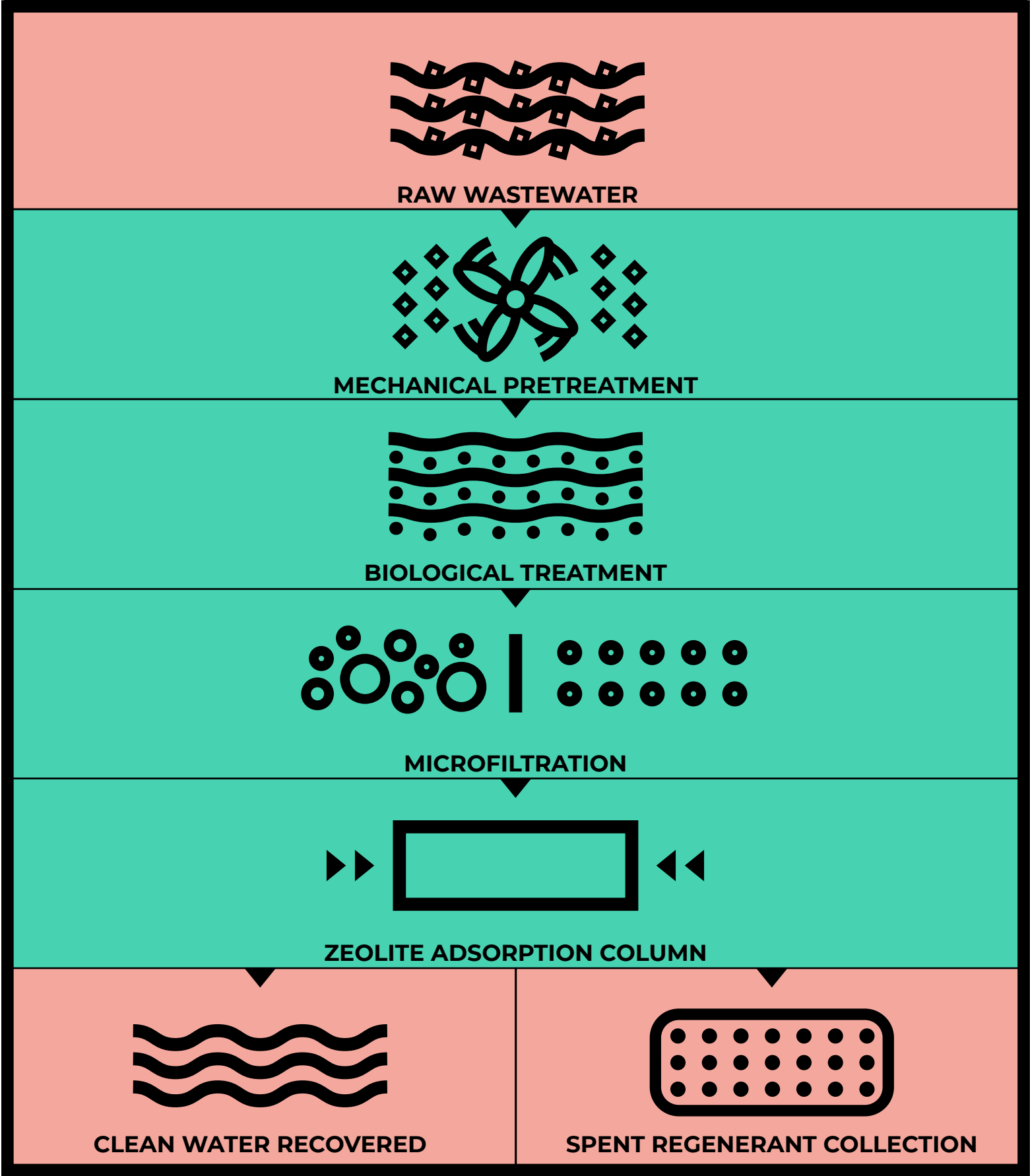
In order to obtain a more sustainable and energy-efficient approach, steps within the conventional N-cycle should be eliminated. In Flanders (Belgium), currently 0.5-0.7% of the total electricity use is associated with urban WW transportation and treatment by the conventional activated sludge (CAS) process (0.25-0.30 kWh/m³ of treated WW).

This study aims to close nutrient cycles by exploring the potential of a 2-stage technology connecting WW treatment and agriculture needs by treatment of real domestic WW by high-rate activated sludge (HRAS) and subsequent recovery of N from the effluent using natural zeolites as adsorption material. HRAS is an alternative system with a better energy balance and less emissions, but it cannot be used on its own because of the insufficient N-removal. Consequently, HRAS must be combined with another technology in order to meet discharge limits (European and Flemish standards) and to valorise relevant resources present in the WW. The process demonstrated N and C-removal efficiencies, ranging from 74% to 82% and 76% to 89%, respectively. An adsorption capacity of 4g N/kg of zeolites was achieved. The N-content of the regeneration liquid was about 755 mg NH_4^+ -N/L.



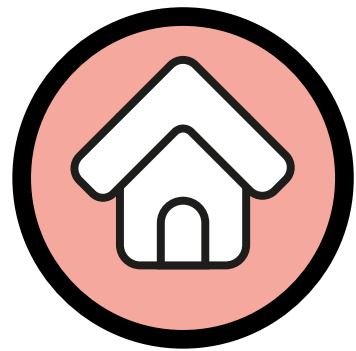
Technology

After a mechanical treatment, the influent of the full-scale wastewater treatment plant of Aartselaar was used. By treating the same influent as the full-scale plant, researchers ensured realistic conditions, accounting for daily fluctuations like weather and peak loads (Technology Readiness Level 5). A sequencing batch reactor (SBR) with a volume of 324L was used for the cultivation of a high-rate activated sludge (HRAS) biological treatment system. Effluent from the HRAS system was first stored in a buffer tank, then pumped through a microfiltration membrane to eliminate suspended solids, minimising the risk of clogging, before being directed into a column, filled with natural zeolites as adsorption material. Flow during saturation was bottom-to-top. Columns of varying sizes could be used, with a maximum flow of 70 L/h. Once a breakthrough was observed (based on $\text{NH}_4^+\text{-N}$ removal efficiencies), the saturated zeolites could be harvested by replacing the cartridge. The system allowed the regeneration using KCl and reverse flow (top-bottom). The setup included a tank designed to collect the spent regenerant, specifically the fraction with the highest $\text{NH}_4^+\text{-N}$ concentration.

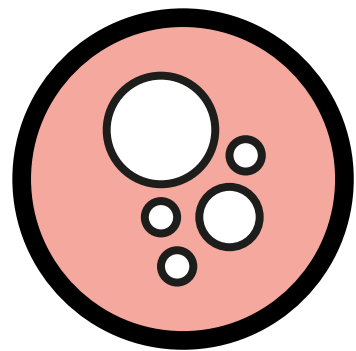


Characteristics

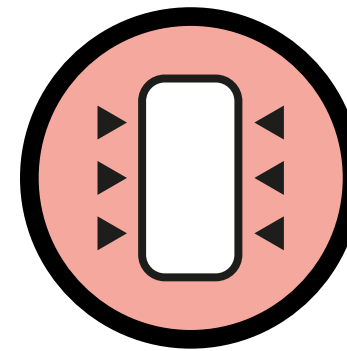
Within WaINUT the integration of HRAS and adsorption processes in a novel two-stage waste water treatment and nutrient recovery system was explored. The HRAS process serves as the first stage, removing organic matter and capturing it in the sludge. In the second stage, N (in the form of ammonium) is removed and recovered using adsorption/ion-exchange (IEX) to produce fertilisers.



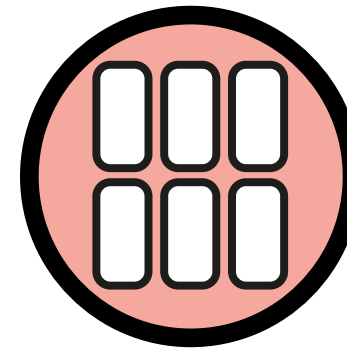
Domestic WW, typically low in organic matter and nutrients, presents challenges in achieving the desired HRAS outcomes. Maintaining a proper balance between SRT and a sufficiently high OLR is essential for system stability.



HRAS offers a higher BMP compared to CAS, leading to increased biogas production during anaerobic digestion. Moreover, HRAS typically results in negligible N₂O emissions, making HRAS a more environmentally friendly option that enhances energy recovery and reduces greenhouse gas emissions in WW treatment.



Treating HRAS/CS effluent with the zeolite adsorption column (pilot-scale) to meet N-related discharge limits was successful. WW volumes between 8-150 bed volumes (BV) could be treated at flow rates of 5-15 BV/h, with no significant differences in treatment capacity observed across this range.

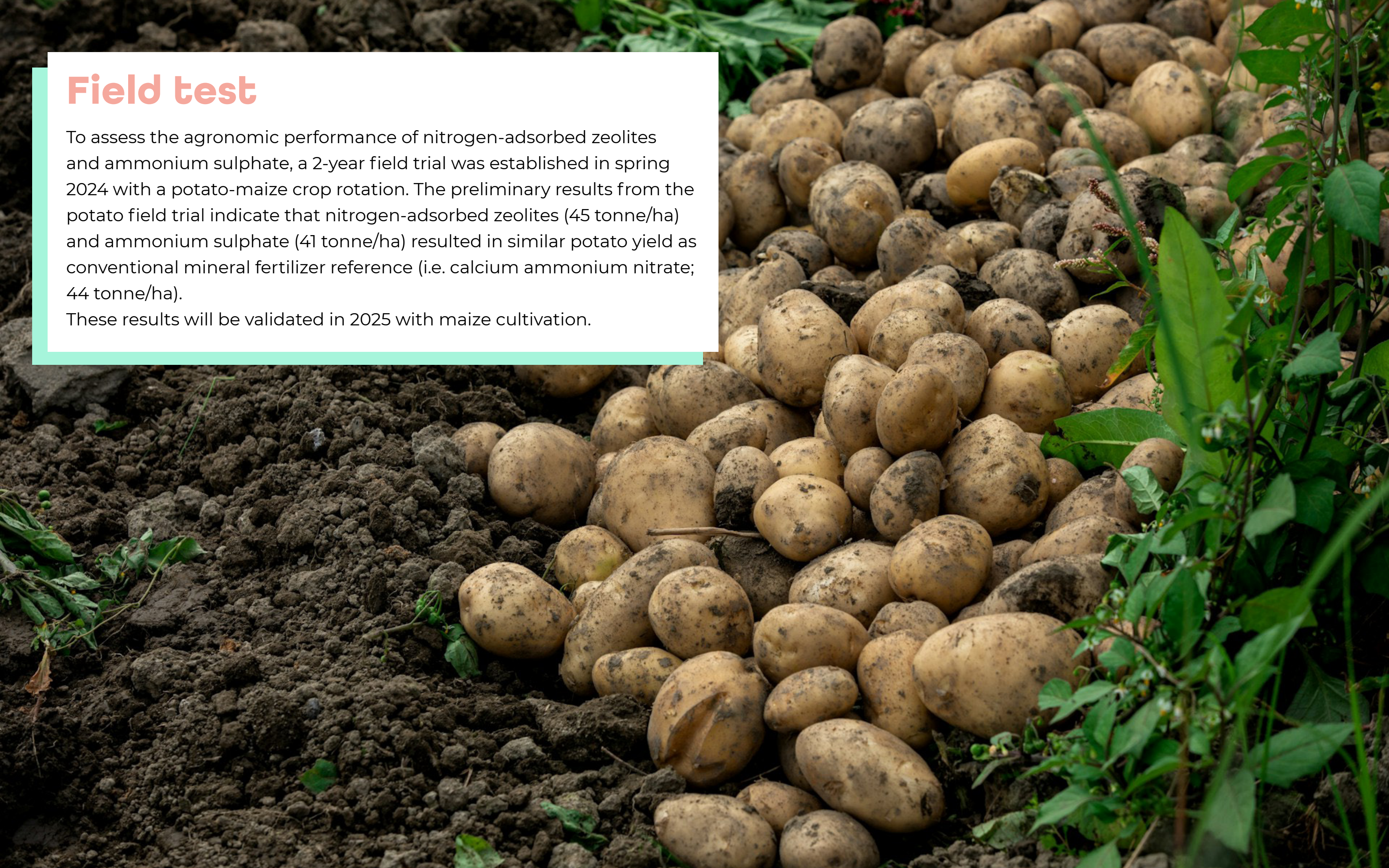


A CAPEX/OPEX analysis of the proposed 2-stage technology revealed that using zeolites in a single-use configuration is about 13 times more expensive (39 EUR/kg Nrecovered) than the reference technology (N-stripping/scrubbing), while regenerating the zeolites increases costs (172 EUR/kg Nrecovered) by nearly 57 times.

Field test

To assess the agronomic performance of nitrogen-adsorbed zeolites and ammonium sulphate, a 2-year field trial was established in spring 2024 with a potato-maize crop rotation. The preliminary results from the potato field trial indicate that nitrogen-adsorbed zeolites (45 tonne/ha) and ammonium sulphate (41 tonne/ha) resulted in similar potato yield as conventional mineral fertilizer reference (i.e. calcium ammonium nitrate; 44 tonne/ha).

These results will be validated in 2025 with maize cultivation.





factsheet URBAN june 2025

Credits

Lennert Dockx, Aquafin NV - Bart Saerens, Aquafin NV - Francis Meerburg, Aquafin NV
Sarah Moreno Sayavedra, Ghent University - Ivona Sigurnjak, Ghent University



walnutproject.eu



info@walnutproject.eu



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101000752.