The successes of the BioDEN-project

The aim of the CORNET-TETRA BioDEN project is to create additional income for the biogas sector by achieving higher digestate value and increasing biogas and biomethane production. The project focuses on several elements: (i) enhanced biogas production through anaerobic digestion (AD), (ii) ammonia recovery through stripping and scrubbing, (iii) phosphorus recovery through precipitation and adsorption.

Increased biogas production

Recirculation of vacuum stripped digestate derived from nitrogen-rich chicken manure reduced the total ammonia nitrogen in the digester by 27%. This prevented inhibition of the digestion process and resulted in increased methane production of 0,31 L/g-VS compared to the test reactor where inhibition did occur.

Lab scale experiments with cattle slurry clearly showed that recirculation of air stripped digestate results in a limited increase of the biogas yield when nitrogen inhibition does not occur. A better yield is obtained when the stripped digestate is post digested. Semi-continuous long-term tests show an additional biogas yield of 6,5 L/kg manure. The same high result is not achieved in pilot-scale tests with a mixture of manure and organic biological waste. Post-digestion is particularly interesting with fibre-rich and recalcitrant input streams.

Nitrogen recovery

A higher stripping temperature (70°C) gives better results for solubilisation of the organic matter and for TAN removal. The effect of lowering pH (from 9.5 to 8) is very limited. The nitrogen-rich air stream obtained is typically scrubbed with sulphuric acid. The project sought a safer and more sustainable organic alternative in citric acid and waste sulphuric acid. At lab scale, 91% of the nitrogen present in digestate from cattle manure could be recovered in sulphuric acid (1 M) and 84% in citric acid (60 g/L) with final concentrations of 4,5 g N/kg and 6,2 g N/kg, respectively.

During pilot-scale tests, stripping efficiency drops drastically to 52% on average. Nitrogen concentrations in the ammonium salts with sulphuric acid, waste acid and citric acid are significantly higher, reaching 88 g TAN/kg, 74 g TAN/kg and 75 g TAN/kg, respectively.

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Phosphorus leaching and precipitation at farm-scale

Farm-scale phosphorus recovery from the solid fraction of digestate was performed at Ivaco site by UGent Re-Source Lab. Preliminary tests were initially done at lab-scale and further scaled up to validate phosphorus leaching from the solid fraction of digestate using waste sulfuric acid, and then precipitation to obtain struvite-like end products. Despite lower phosphorus recovery rates compared to the lab-scale tests, struvite-like precipitates were still successfully obtained. Lower recovery rates are often faced when processes are scaled up due to a less controlled operating environment, such as the development of dead zones in mixing tanks and/or lower speed of centrifuge at large-scale.

An excursion and demonstration at the pilot site took place on 30 April 2024, organised by the UGent Re-Source lab, with the participation of Biogas-E and VCM. Below are some some images of the excursion, also visit the pilot plant virtually via this video.

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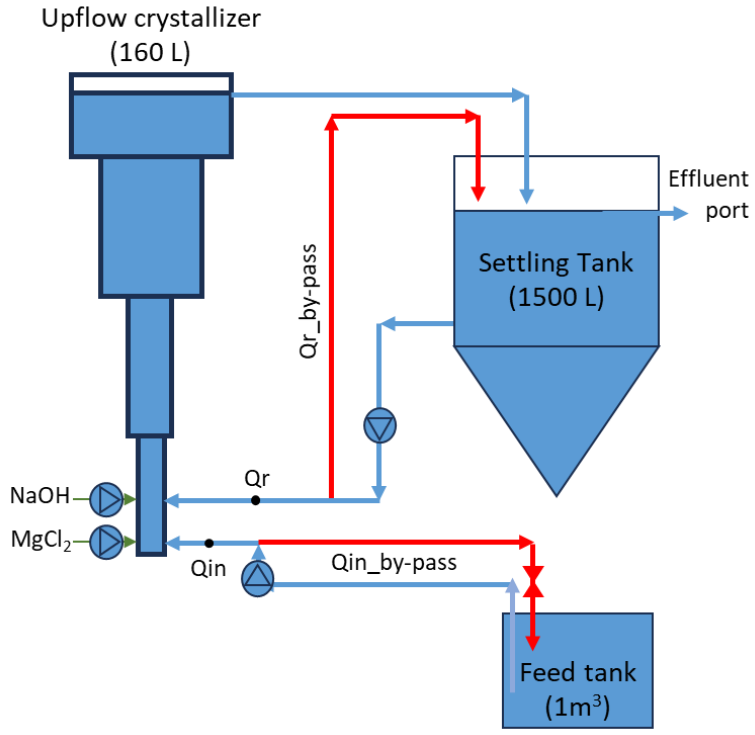
Phosphate recovery from liquid fraction of digestate (LFD)

In Task 3.1, Marmara University group (TR) evaluated the applicability of **struvite crystallisation** for recovering phosphate from the liquid fraction of digestate (LFD). Optimal operational conditions were determined through lab-scale tests using synthetic phosphate solution and real digestate. The efficiency of phosphate recovery was assessed, and composition of the recovered products were analysed using X-ray diffraction (XRD) and scanning electron microscopy-energy dispersive X-ray spectroscopy (SEM-EDX).

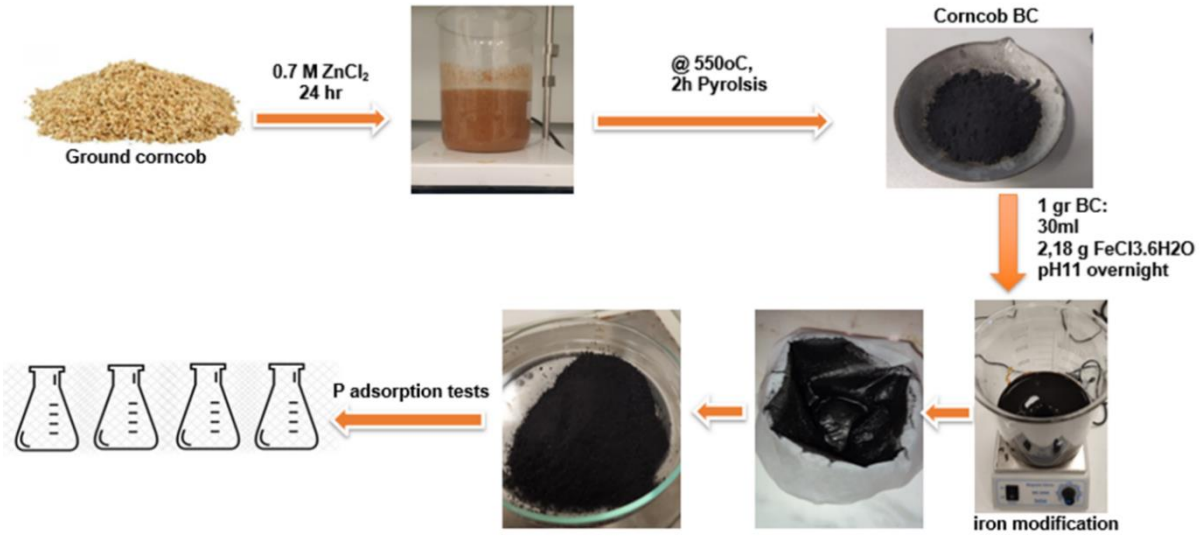
Struvite recovery experiments were first conducted in batch-mode using a 4,5 L upflow fluidized bed crystallizer (FBC) filled with 3,5 L chicken manure digestate. The LFD was circulated from the bottom of the FBC with an upflow velocity of 20 cm/min for 24 h. $MgCl_2$ was supplemented to adjust the Mg:P molar ratio to 1:1 at the beginning of the experiment. Almost 80% of the phosphate was recovered in 24 h and 75% of the recovery was accomplished in the first hour.

After completing the laboratory-scale batch experiments, a pilot-scale upflow reactor was installed at SELEDA's Biogas Plant in Babaeski, Turkiye. SELEDA is one of the SMEs in the User Group of the BiODEN Project. In each experiment, the pilot reactor operated for 6-8 hours, receiving a continuous feed of LFD at a rate of 160-180 L/h. The upflow velocity was adjusted to 1800-2000 L/h with the help of internal recirculation.



Similar to laboratory-scale batch experiments about 80% of phosphate was removed from LFD through struvite crystallization in the pilot-scale continuously fed, upflow reactor. The figure above shows the schematic of the pilot setup and a photograph taken during its operation.

In Task 3.2 the applicability of **Fe-modified biochar** as an adsorbent for phosphate recovery from liquid fraction of digestate (LFD) was assessed. Although biochar is a relatively inexpensive adsorbent, its negatively charged surface makes it unsuitable for phosphate adsorption. In the study biochar derived from corncobs is modified with iron to enhance its phosphate adsorption capacity. Fe-modified biochar production procedure is described in the following figure as a flowchart.



Fe-modified biochar samples were tested in bench-scale batch experiments using synthetic and real digestate samples for phosphate recovery. 50 mL chicken manure digestate with a PO_4^{-3}-P concentration of 230 mg/L was filled in 100 mL glass flasks without pH adjustment. Flasks were shaken for 90 min.

Based on the results, Fe-modified biochar's adsorption capacity for phosphate was estimated to be 33 mg/g according to Langmuir adsorption model. As the biochar dosage increased, phosphate removal also increased, reaching up to 93%. However, it is noted that the phosphate adsorption capacity of the Fe-modified biochar decreased with an inverse proportion to the removal rate. In summary, Fe-modified biochar is concluded to be a promising adsorbent for phosphate recovery.

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Agro-environmental assessment of the fertilising products

The potential phosporus fertilisers recovered from the liquid fraction (see Factsheets 3.1 and 3.2) and solid fraction (see Factsheets 3.3 and 3.4) of digestate were tested in pot trials using ryegrass and compared to commercial mineral phosphorus fertiliser (triple super phosphate - TSP) by UGent Re-Source Lab. Rye grass was cultivated in controlled conditions for 12 consecutive weeks. All struvite-like fertilizers demonstrated a similar performance to TSP, with high phosphorus fertilizer replacement values (PFRV) ranging from 98% to 128% in the third cut. In contrast, iron-modified biochar had a significantly lower PFRV of 58%. Moreover, the addition of ammonium citrate did not have a remarkable enhancement on phosphorus uptake.

The residual fraction of the digestate, after recovering nitrogen and/or phosphorus, was also evaluated for its potential as a soil enhancer. The carbon mineralization of both P-poor and N- and P-poor fractions were stabilized around 15% of the added carbon, indicating a promising result for high Effective Organic Matter.

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One of the innovations of the project is to combine the aforementioned technologies in six different technology cascades. The technical, economic and environmental performance of the different cascades compared to the current situation is under evaluation. Be sure to keep an eye on the project website to see the latest results.

Would you like more information about the BioDEN project in general? Contact: info@biogas-e.be

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