Interreg Austria – Czechia
Co-funded by the European Union

From Waste to Resource
Recycling Sewage Sludge Ash into Phosphate-rich Plant Fertilizer

How the phosphorus contained in sewage sludge can be used to improve the closing of the phosphorus cycle.

Motivation

Phosphorus is essential for food production but is limited, regionally concentrated, and mined under harmful conditions. It has been on the EU's critical raw materials list since 2014 due to its importance and high import dependency. Around 90 % of phosphorus in wastewater is retained in sewage sludge – nearly 7,000 tons yearly in Austria and 8,000 tons in the Czech Republic.

Sewage sludge use differs: in the Czech Republic, agriculture remains dominant, whereas Austria incinerates most sludge, with Vienna using mono-incineration. By 2033, Austria will mandate incineration for larger treatment plants, requiring 80 % phosphorus recovery from ash. The Czech Republic plans stricter laws limiting agricultural use, pushing for alternative sludge disposal, with thermal utilization as the primary option.

The current state of the research in Work Package 1

Advancing Phosphorus Reclamation from Sewage Sludge

To gain a comprehensive understanding of sewage sludge composition in the project-relevant regions – Czech districts such as Jihomoravský district and Vysočina district, as well as Austrian federal states – Upper Austria, Lower Austria and Vienna, samples were collected from 13 Czech and 10 Austrian wastewater treatment plants. Using modern analytical techniques, including ICP, XRD, elemental analysis, and traditional methods such as calorimetry and proximate analysis, we built a detailed database covering macro- and micro-element compositions, fuel properties, and other key variables for a total of 23 samples.

With this dataset in hand, the consortium identified sludge samples with the most promising characteristics for further research and phosphorus reclamation, aiming to develop a suitable fertilizer. Key selection criteria included at least an average phosphorus content, high dry matter and ash content, and significant residual heavy metal concentrations. While heavy metals in sludge can pose processing and quality challenges – since they tend to bio-leach alongside phosphorus forms – samples with higher heavy metal content offer the greatest potential to see the procedure effect and the best potential for improvement through targeted processing.

A literature review conducted as part of Work Package 1 guided the selection of promising additives to facilitate the volatilization of heavy metals. The goal was to produce less-contaminated ash as an intermediate product of thermal processing, forming the first stage of the phosphorus reclamation process. Laboratory-scale tests at Brno University of Technology (BUT) evaluated the effects of various additives – including hydrates of $AlCl_3$, $MgCl_2$, $MgSO_4$, $Al_2(SO_4)_3$, $CaSO_4$, as well as non-hydrated $CaCl_2$, $CaSO_4$, $FeCl_3$, and NaCl – using a modern design of experiments methodology approach. These tests examined how different additive types, concentrations, and combustion temperatures influenced phosphorus retention and residual heavy metal concentrations in the resulting ash on the laboratory scale. The first sample batches have been formed (by BUT) and analysed via ICP and XRD (by Masaryk University), with data processing currently underway.

Scaling Up: Pilot-Scale Testing and Process Verification

In parallel, BUT enhanced and modified its pilot-scale technology, including a rotary dryer and rotary sintering kiln, to handle sludge as an input and produce ash at a larger scale for project partners. A key development was the design and implementation of a custom sludge doser (see Fig. 1A), which addresses the challenge of handling dewatered sludge – a complex material in terms of flow properties – within a rotary dryer. The new system enables the production of small ash clumps with large specific surface areas (sludge pieces before drying are visible in Fig. 1D), making them ideal for bioleaching.

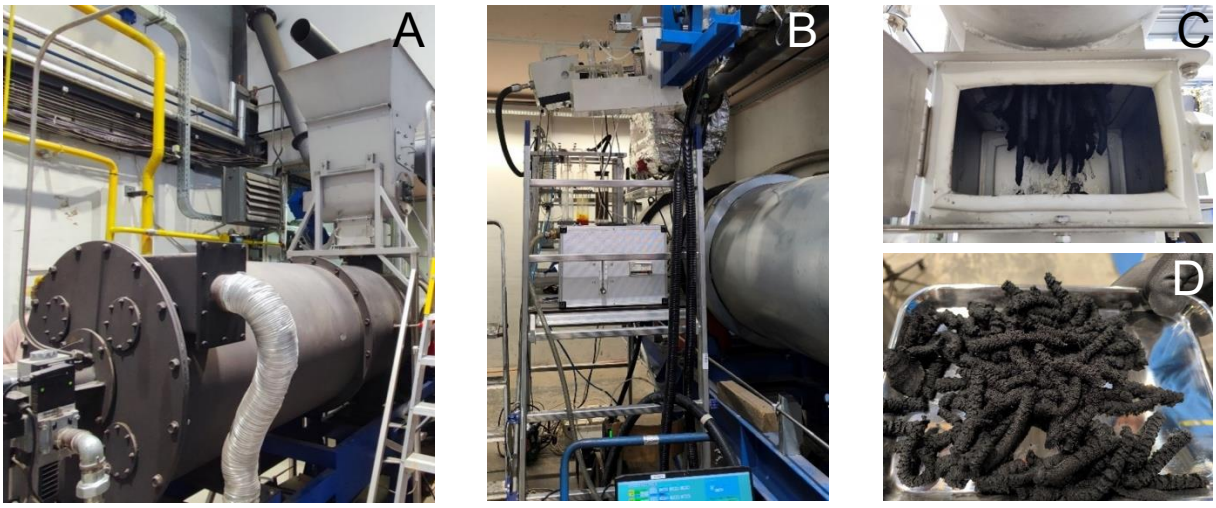

Figure 1 (A – D): A) Pilot scale rotary dryer modified by implemented custom experimental sludge doser, B) Sludge incineration with emission measurement (mainly manual measurement equipment for heavy metals and chlorine determination can be seen); C) Experimental sludge doser in action, D) Detail of resulting sludge pieces before drying.

The first pilot-scale tests, simulating near-industrial conditions, were successfully conducted. A total of 0.75 tons of sludge was processed, divided into three variants: one without additives, one with $MgSO_4$ hydrates, and one with $MgCl_2$ hydrates. These large-scale trials yielded significant quantities of ash suitable for bioleaching experiments, with magnesium addition also supporting subsequent struvite formation. Additionally, the trials provided crucial data on heavy metal mobilization from solid sludge into the gas phase. Currently, the resulting ash samples and pilot-scale emission data are undergoing further analysis.

This progress marks a significant step toward optimizing sewage sludge treatment for phosphorus recovery while addressing heavy metal contamination. Stay tuned for further insights as the research advances.

Dissemination activities

K1-MET presented the PHOS4PLANT project at the national network event „vernETZt im Donauraum – Verbindungen schaffen, Zukunft formen“ in Linz, Austria, on 10 – 11 March 2025.

Brno University of Technology (BUT) has successfully engaged students in the project’s research areas. Notable example is a bachelor's thesis titled “Treasure in the Sludge: Phosphorus Recovery through Ash Bioleaching Innovation,” which directly aligns with the project’s objectives. The thesis is nearing completion, with its defense scheduled for this summer.

Masaryk University, as part of a project, has developed and submitted for publication in the prestigious journal a new methodology that enables the simultaneous analysis of bacteria and archaea in various types of environmental samples, such as wastewater treatment plant sludge or bioreactor samples. A talented high school student also contributed to the processing of metagenomic sequencing data from soil samples, and with this project, he advanced to the national round of the Stockholm Junior Water Prize competition, organized by Mendel University in Brno. Furthermore, the results of the study on the limitation of bacterial sulfur oxidation were presented at the 6th International Scientific Conference Biotechnology and Metals, held in Stara Lesná, High Tatras, on 10 – 11 October 2024. The abstract was later published in the proceedings Biotechnology and Metals 2024.

BOKU University organized a Stakeholder dialogue with it's industrial co-financing partner (Land Niederösterreich, EVN and Timac Agro) and discussed the exploitation of the results in the Interreg AT-CZ region.

Involved partners

K1-MET has proven expertise in the further development of processes for the treatment of residues and recycling materials with the aim of recovering valuable materials and closing material cycles. The tasks of K1-MET are, therefore, the recovery of phosphorus from sewage sludge ashes by non-contact bioleaching or with acids and the subsequent production of the phosphate-rich plant fertilizer. This is combined with the removal of impurities, such as metals, from the sewage sludge ashes. K1-MET is the lead partner in this project.

Masaryk University (MU) is the second-largest university in the Czech Republic. The Department of Biochemistry, the Department of Chemistry, and the Department of Geological Sciences are involved in the project. The team has many years of experience in the field of acidophilic microorganisms, molecular mechanisms of plant-microorganism interactions, structure-function analysis of microbial communities, mineral analysis, and trace element analysis.

A team from the Department of Thermal Processes and Gas Cleaning which is a part of the Institute of Process Engineering of Brno University of Technology (BUT) is involved in the project. This team has extensive experience in the field of thermal processes and emission treatment. They are responsible for the production of sewage sludge ash in the project. The institute possesses a drum dryer and a rotary kiln necessary for pilot-scale experiments. In addition, analytical infrastructure is available to measure fuel and waste properties and to analyze flue gas emissions.

The Institute of Waste Management and Circularity (ABF-BOKU) is focused on the safe disposal and recycling of waste in order to reduce the amount of waste and to save resources in primary production. Its tasks in the project are the pre-treatment of the highly alkaline ashes, which hinder the biological leaching of the material, the bioleaching of sewage sludge ashes, and the identification of acidophilic bacteria from sewage sludge. In addition, the entire process chain will be evaluated using LCA.

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