

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 an essential fertilizer in the agricultural 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, beside onsite solutions, the incineration for larger wastewater treatment plants, requiring 80 % phosphorus recovery from the ash. The Czech Republic plans stricter laws limiting agricultural use, pushing for alternative sludge disposal, with thermal utilization as the primary option.

Recovery of phosphorous from sewage sludge ash is challenging due to the co-pollution with heavy metals. In addition, the use of industrial acids for leaching and consequent precipitation renders it an economically and environmentally challenging process. In PHOS4PLANT, alternative ways for incinerating sewage sludge, leaching, and precipitating phosphorous are explored that could represent an environmentally friendly alternative to obtain high quality fertilizer based on biological processes.

The current state of research in Work Package 1

Improving the Ash: Additivation and Combustion Trials

Everything that comes later in the PHOS4PLANT project depends on the material made in Work Package 1: a sewage sludge ash from which phosphorus can be released, and whose heavy metal load will not compromise the final fertilizer. Two activities are shaping that material — laboratory-scale optimization of additivation and pilot-stage combustion at BUT (Activity 1.2), and carbonation of the resulting ash at BOKU University (Activity 1.3).

The programme of BUT laboratory-scale activities is built around a design of experiments (DOE) methodology, which allows the influence of several process parameters — additive type, dosing, combustion temperature and selected residence time — to be assessed simultaneously rather than one at a time. The trials have so far been run primarily on CZ6, the representative Czech sludge chosen during the earlier screening campaign.

The results obtained so far have already redirected the choice of additives. Sulfate-based additives, promising in the initial screening, proved unsuitable in practice: their use is accompanied by a marked increase in SO₂ emissions, difficult and costly at industrial scale. Attention has therefore shifted to other types of additives, which promise a more favourable influence on heavy metal volatilization while keeping phosphorus in the ash. The resulting ash series are being analysed (ICP and XRD) together with Masaryk University (MU). In parallel, Austrian sludges were also characterized in detail at BUT and MU.

Conditioning the Ash: Carbonation to Lower the Acid Demand

Bioleaching with *Acidithiobacillus thiooxidans* works best in a distinctly acidic environment, at a pH of roughly 2.0 to 3.5. Sewage sludge ash, on the other hand, is frequently alkaline, and bringing it into the working range consumes acid that must first be produced or purchased. Activity 1.3 asks whether a carbon dioxide treatment can do part of that work in advance. BOKU University exposed two ashes from the first pilot incineration at BUT — one produced without additives, one additivated — to either pure CO₂ or ambient air for 48 hours in flow-through columns, at liquid-to-solid ratios between 0.0 and 0.8, each condition in triplicate.

The most tangible outcome of these trials concerns the acid demand of the non-additivated ash. Titration with 0.5 M sulfuric acid showed that the untreated material required 3.58 ± 0.32 mL to reach pH 3.5, whereas the same ash after carbonation needed only 2.77 ± 0.31 mL — a reduction of about a fifth in the acid consumed during the critical early stage of leaching, when a rapid drop in pH keeps the acidophilic culture productive. Continued acid addition, however, brought the carbonated and the non-carbonated ash to practically the same end point of pH 1.85 ± 0.11 , which indicates that the benefit of carbonation is confined to the beginning of the leaching process.

The amount of carbonate actually formed was, by contrast, modest. Total carbon in the treated ashes remained between 0.1 and 0.3 % of dry matter, at the detection limit of the analyser, with no clear trend across the liquid-to-solid ratios tested and no measurable advantage of pure CO₂ over ambient air. A likely explanation lies in the ash itself: in contact with deionized water the non-additivated ash from the rotary kiln unexpectedly reacted slightly acidic to neutral (pH 5.9 to 6.3), unlike the distinctly alkaline ashes reported for fluidized-bed combustion. An ash that is already close to neutral simply gives less carbonation to work with.

The additivated ash behaved differently, and not in the expected direction. Its aqueous pH was markedly more alkaline (8.3), plausibly linked to the magnesium sulfate additive. Carbonation lowered that pH by 1.8 to 2.1 units, yet the material buffered so strongly during titration that pH 3.5 could not be reached at all, even after the addition of 9.99 mL of 0.5 M sulfuric acid. For this ash, additivation increased rather than reduced the acid demand — a result worth knowing before it is discovered at pilot scale.

On the basis of these data the carbonation parameters were fixed at 20 °C, 100 % CO₂, a treatment time of 48 hours and an initial liquid-to-solid ratio of 0.3, and ash treated under these conditions is now being prepared for project partner K1-MET. A standard operating procedure was written to keep sample preparation and column construction uniform between runs, and the summary of the obtained carbonation data for the different ashes was completed.

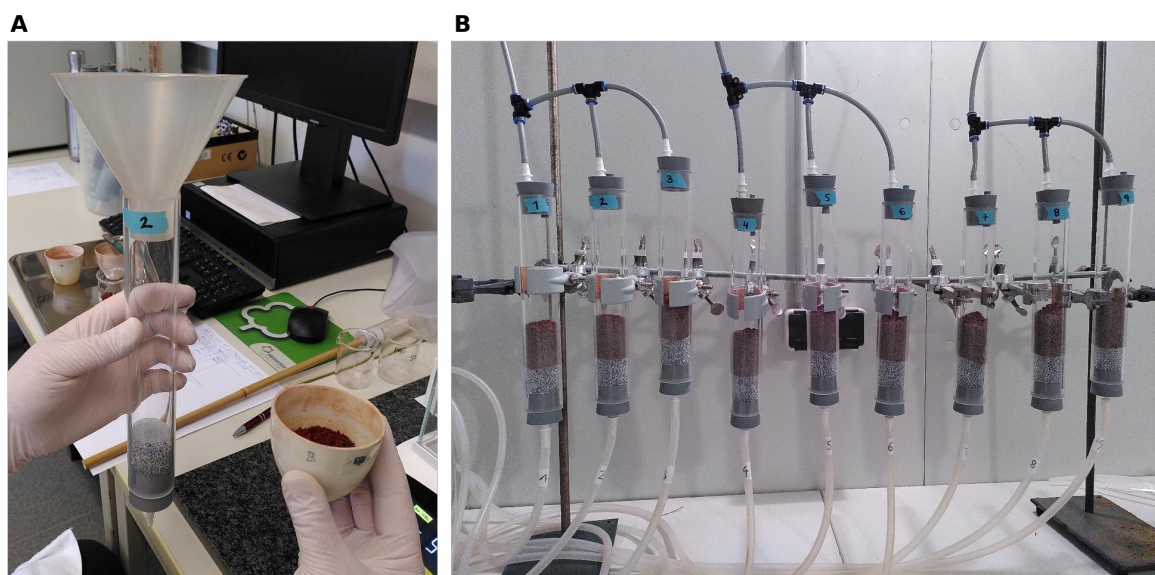


Figure 1: Carbonation trials at BOKU University on sewage sludge ash produced by BUT. A) Filling of a prepared column with moisturized ash; B) Setup of the flow-through carbonation trials with nine connected columns containing ashes from the pilot incineration at BUT.

Looking Ahead: Towards the Second Pilot Campaign

Work Package 1 now moves from characterisation towards a second, better-informed pass through the ash preparation chain. Four lines of work occupy the current and upcoming months:

- Selection of the Austrian sludge feedstock – analyses at BUT and MU are completed, and the Austrian sludge AT9 offers the most favourable composition overall for WP 1.
- Waste-derived additives – candidate materials from waste streams, among them eggshells, brines and salt solutions (aluminium sludge) and PVC are being sourced, characterized and screened at laboratory scale (BUT+MU) as replacements for commercial pure reagents, in keeping with the circular-economy logic of the project.
- A second pilot campaign – the selected additivations will be applied to the Austrian-origin sludge in a second pilot-scale drying and incineration run, producing a fresh batch of ash.
- A further round of carbonation – the trials with additivated and non-additivated ash alike showed only limited carbonation and pH reduction, and, unlike the typically alkaline ash from fluidized-bed combustion, the non-additivated ash reacted slightly acidic to neutral in water. Further pilot trials with other types of sewage sludge ash could provide suitable samples; if a higher initial pH can be reached in those, the potential effect of carbonation on the subsequent leaching and fertilizer production could be evaluated for them as well.

Taken together, the presented two activities give an actual picture of the project's front end: the laboratory work aims to identify the additives worth using in the next pilot run, while the carbonation trials serve to quantify the potential for reducing the consumption of pH-lowering agents.

Dissemination activities

As part of Masaryk University's dissemination activities, a study on sulfur trafficking in a model acidophilic sulfur-oxidizing bacterium was presented at the 26th International Biohydrometallurgy Symposium (IBS 2026), held on 28–30 September 2026 in Orléans, France. An extended abstract was published in the conference proceedings. The PHOS4PLANT project was also presented during Researchers' Night on 25 September 2026 at the University Campus in Brno. In addition, high school student Michaela Dvořáková investigated a biogenic schwertmannite–magnetite composite for phosphorus recovery in her PHOSMAG research project. Her work advanced to the regional round of the 2026 Czech Secondary School Research Competition (SOČ), contributing to the dissemination of project-related research among young researchers.

Brno University of Technology (BUT) took part in the 2nd project workshop, hosted by BOKU University in Vienna on 22 April 2026, contributing a presentation “Motivation of phosphorus reclamation from the sewage sludge” by Vladimír Brummer. The manuscript prepared by BUT together with the project partners, titled “A Pilot-Scale Preparation of Pre-Treated Sewage Sludge Ash for Phosphorus Reclamation” is being iteratively improved and is nearing its submission. Bernadette Goma also presented the contribution “Thermochemical removal of heavy metals from sewage sludge” at the 13th International Conference on Energy, Sustainability and Climate Crisis held in Rethymno, Greece, on 24–28 August 2026. BUT is also currently hosting the International Engineering Project Weeks – Autumn 2026 at the Institute of Process Engineering, held from 31 August to 25 September 2026 on the topic “Integrated Waste Management and Treatment Processes”. The programme has brought a group of exchange students from Germany (Augsburg) to Brno and introduced them, through supervised project work, to a range of topics including waste treatment and phosphorus recovery – the main subject of the PHOS4PLANT project.

BOKU University presented the results on the carbonation of sewage sludge ashes at the 13th International Conference on Sustainable Solid Waste Management, held on Kos Island in Greece, from 24–27 June in 2026.

Involved partners



K1-MET GmbH 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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Responsible for the content: Vladimír Brummer (BUT), Hannes Konegger (ABF-BOKU), Christian Zafiu (ABF-BOKU) Page 6