

Best available techniques to recover or recycle fertilizing products from secondary raw materials

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Nutrient recovery emerges as a cornerstone of the circular economy, addressing the urgent need to mitigate the environmental impact of human activities while ensuring the long-term sustainability of natural resources (Valve *et al.*, 2020). In a global context marked by rising demand for food and agricultural products, the intensive extraction and consumption of finite resources, such as phosphorus and nitrogen, have led to significant ecological and economic imbalances. The traditional linear model of resource use—characterized by extraction, consumption, and disposal—has proven unsustainable, prompting a shift toward more regenerative systems. Nutrient recycling plays a crucial role in this transition, transforming waste generated in agricultural, industrial, and urban systems into valuable inputs like fertilizers, thus closing nutrient cycles and reducing dependency on non-renewable resources.

This approach not only addresses the depletion of critical resources but also mitigates pressing environmental issues. For instance, excessive nutrient runoff from agricultural and urban waste contributes to the eutrophication of aquatic ecosystems, leading to the proliferation of harmful algal blooms and the depletion of oxygen in water bodies. Additionally, the mismanagement of organic waste generates greenhouse gas emissions, particularly methane and nitrous oxide, exacerbating climate change. Nutrient recovery processes, by recovering essential elements from organic waste (Dadrasnia *et al.*, 2021), wastewater (Saliu & Oladoja, 2021), and industrial by-products, enable their reintegration into agricultural systems, promoting efficient and sustainable resource utilization.

The alignment of nutrient recycling with circular economy principles underscores its potential to create economic and environmental value. By valorizing waste materials, this strategy fosters innovation in recovery and processing technologies, unlocking new economic opportunities. Advanced methods such as nutrient separation, optimized composting (Lopes *et al.*, 2021), anaerobic digestion (Rizzioli *et al.*, 2023), and struvite crystallization (Wu & Vaneeckhaute, 2022) have shown promise in producing high-quality fertilizers while minimizing environmental harm. These technologies exemplify how waste can be reimagined as a resource, reducing the need for synthetic fertilizers and enhancing soil health.

Beyond its environmental benefits, nutrient recovery contributes to food security and the resilience of agricultural systems (Arcas-Pilz *et al.*, 2021). As climate change and resource scarcity pose growing challenges to global food production, integrating nutrient recycling into agricultural practices can reduce vulnerability and enhance adaptability. By closing nutrient loops, this approach supports regenerative agricultural models that prioritize long-term soil fertility and ecosystem health, ensuring the productivity and sustainability of farming systems for future generations.

The main goal of the FertiCovey project is to analyze best available technologies for recycling fertilizers from secondary raw materials. It advises policymakers and stakeholders on alternative fertilizing products, ensuring balanced nitrogen and phosphorus flows and promoting soil health and structure within ecological limits at regional and local levels.

The impact of the FertiCovey project focuses on transforming nutrient management towards a more sustainable model, aligned with the principles of the circular economy. Through the identification and evaluation of advanced technologies for nutrient recovery and bio-based fertilizer production, the project contributes to reducing dependence on chemical fertilizers and mitigating their negative impacts on the environment, such as eutrophication, soil pollution, and greenhouse gas emissions. This transition fosters a more resilient agricultural sector while addressing pressing global challenges related to resource depletion and environmental degradation.

One of the main impacts is the strengthening of agricultural sustainability by promoting the use of alternative fertilizers derived from secondary materials such as manure, digestate, and other organic residues. By converting these materials into valuable fertilizing products, the project not only preserves key resources such as phosphorus and nitrogen, but also enhances soil health, boosting its organic matter content and fertility. This approach plays a crucial role in maintaining biodiversity and ensuring long-term productivity in agricultural systems.

FertiCovery also has a significant impact on building favorable regulatory and policy frameworks. By providing technical, environmental, and economic insights into nutrient recovery technologies, the project equips policymakers, regulatory bodies, and other stakeholders with the evidence needed to create supportive policies. This facilitates the removal of barriers to market entry, ensuring that bio-based fertilizers gain wider acceptance and adoption in local and regional markets.

At the societal level, the project fosters awareness and acceptance of bio-based fertilizers through an inclusive and collaborative approach. Workshops, open forums, and educational materials target diverse audiences, including farmers, scientists, industries, and policymakers. This outreach ensures that project findings are not only disseminated effectively but also encourage dialogue, innovation, and cross-sector collaboration. As a result, the project catalyzes a shift in public perception, driving demand for sustainable fertilizers.

Overall, FertiCovery generates a multifaceted positive impact. By advancing sustainable agricultural practices, reducing environmental degradation, and promoting efficient resource management, the project positions Europe as a global leader in nutrient recovery and bio-based fertilization technologies. Its contributions are expected to have long-lasting effects, fostering ecological balance, economic viability, and societal well-being in alignment with global sustainability goals.

Results

The FertiCovery project aims to develop and promote sustainable solutions for nutrient recovery and recycling, addressing key problems related to the overuse of chemical fertilizers and the under-utilization of organic waste. Among the main expected results is the identification and evaluation of at least 25 innovative technologies for nutrient recovery and bio-based fertilizer production. These technologies will be analyzed considering technical aspects, environmental impacts, health safety, raw material availability and economic viability, as well as the regulatory framework and associated social risks.

The project will culminate in a detailed multi-criteria analysis report and fact sheets describing the 10-15 best available technologies. This will provide policy makers, producers and other key stakeholders with clear and accurate information to make informed decisions on the implementation of these technologies. It will also foster the creation of a favorable framework to overcome regulatory and market barriers that currently limit the adoption of bio-based fertilizers.

FertiCovery will also have a significant impact on knowledge dissemination through the organization of workshops and forums, both virtual and face-to-face, involving a wide range of stakeholders, from researchers and producers to policy makers. This will ensure that the project results are accessible at European and international level, encouraging replication of best practices.

Ultimately, the project will contribute to the transition towards a more efficient circular economy, improving resource management, reducing environmental impacts on soil, water and air, and promoting more environmentally friendly alternative fertilizers. The benefits will extend to society at large, including more sustainable agriculture and the preservation of natural resources.

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