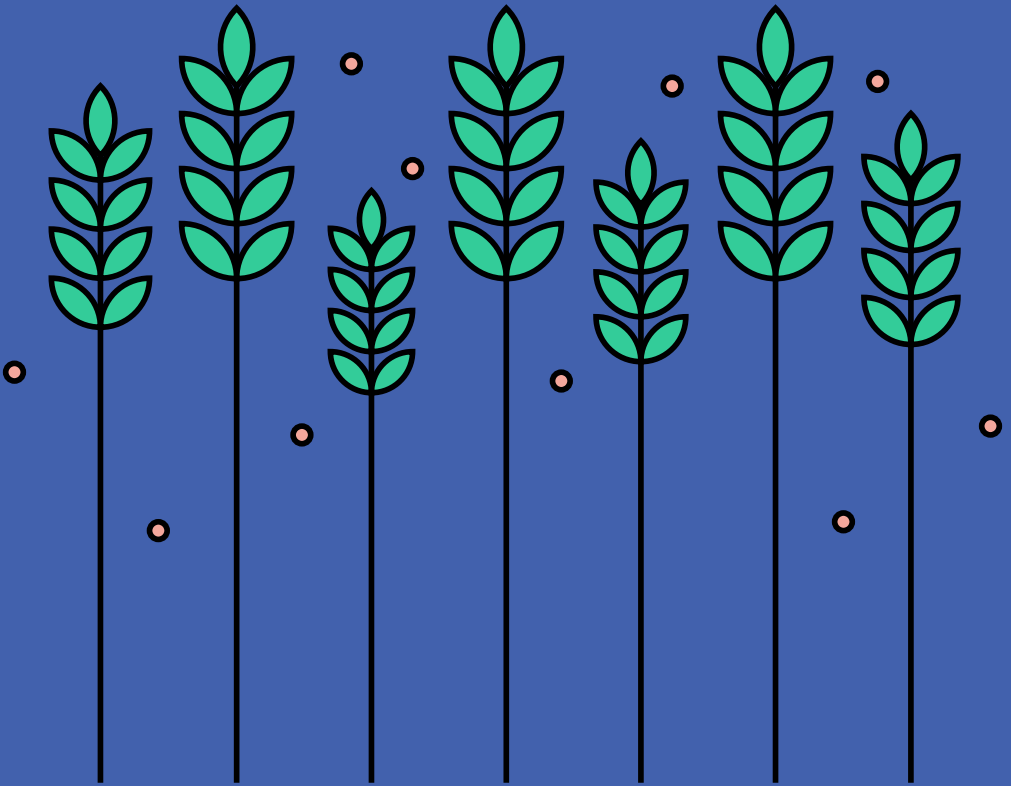




WALNUT



**Best Practices for
Sustainable Bio-Based
Fertilisers in Europe**

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1. INTRODUCTION

This **Best Practice Book** serves as a harmonised reference to guide researchers, industry actors, farmers, and policymakers in understanding, evaluating, and applying bio-based fertilisers derived from wastewater, algae processes, and mineral recovery operations. The BPB includes detailed information on BBF production processes, nutrient composition, field performance, environmental impact, and agronomic efficiency, alongside practical guidance, harmonised evaluation protocols (GEP), and SWOT analyses. By documenting lessons learned, trial results, and maturity levels of BBFs, the BPB supports the adoption of safe, effective, and sustainable nutrient recovery solutions. It compiles the main scientific, agronomic, and methodological insights generated within the project. Together with other documents developed throughout the entire duration of the project (e.g., *White Paper “Good experimental practice protocol”* and the deliverable *“Farmer biobased fertiliser application manual”*).

1.1 About the project

The WalNUT project addresses the growing pressure on the food and agricultural sectors caused by the rising global population and increasing consumption. Traditional farming practices rely heavily on land, water, energy and mineral fertilisers, and they reach their limits while putting soil health and the environment at risk.

WalNUT recovers nutrients from wastewater streams and transforms them into **safe, BBFs**. By closing nutrient cycles, the project promotes a circular, sustainable and resource-efficient model that reduces dependence on non-renewable mineral fertilisers, mitigates environmental impacts, and supports food security.

The project analyses nutrient imbalances across the EU, tests innovative nutrient recovery technologies in five pilot plants at key sites, and evaluates several BBFs, including **ammonium sulphate, nitrogen-loaded zeolite** and the **AS+VZ** (virgin zeolites) **blend, algae powder, Bio-NPK-C, Smart BBFs** and **recovered salts**. It assesses environmental and socio-economic impacts and measures the agronomic performance of the resulting BBFs. WalNUT aligns with the EU Green Deal and contributes to a resilient, sustainable, and circular agri-food sector.

2. LEGENDA

AS	Ammonium sulphate
BPB	Best Practice Book
BBFs	Bio-based fertilisers
CaCO₃	Calcium carbonate
CO₂	Carbon dioxide
CBRN	Chemical, Biological, Radiological, and Nuclear
CMC	Component Material Category
FPR	Fertilising Products Regulation
KCl	Potassium chloride
Mg(OH)₂	Magnesium hydroxide
NZ	Nitrogen-loaded zeolite
PGPB	Plant growth-promoting bacteria
TRL	Technology readiness level
VZ	Virgin zeolites
WWTP	Waste water treatment plant

3. RESULTS AND MATURITY UPSCALING

This section summarises the results obtained for the different BBFs developed within the WaINUT project, highlighting their agronomic performance, operational characteristics and potential for integration into agricultural practices. The evaluation considers crop responses, nutrient availability, environmental outcomes and production process characteristics, providing a basis for assessing the applicability and potential contribution of each BBF to circular nutrient management.

For TRL assessment, all pilot activities were maintained at TRL 5, in accordance with the project proposal.

AS and the AS+VZ blend were applied across different cropping systems. AS, produced via stripping and scrubbing applied to the liquid fraction of digested digestate following separation from the solid fraction, demonstrated a stable composition and good solubility, facilitating application in various trial conditions. When combined with NZ, the AS+VZ blend retained slow-release properties while providing nitrogen levels suitable for field application. Agronomic results showed that AS and AS+VZ supported crop growth and nitrogen uptake comparable to conventional CAN fertiliser, with nitrogen fertiliser replacement efficiencies around 80-92% for AS and 65-90% for AS+VZ. Pot and

nursery trials confirmed that both products were safe for sensitive crops, with no observed phytotoxicity. Environmental monitoring indicated that soil nitrate levels and greenhouse gas emissions were comparable to mineral fertilisers, although additional monitoring for ammonia and methane emissions require further validation.

BIO-NPK-C was derived from food-industry residues using integrated liquid and solid-state fermentation combined with ABC-BioPhosphate adsorption. The process generated a multi-nutrient fertiliser and reusable water while producing surplus renewable energy. Pilot-scale validation demonstrated stable process performance and reproducible product characteristics. Greenhouse trials with tomato showed positive responses in crop yield and nutrient uptake compared with untreated controls and mineral fertilisers. Environmental assessments indicated nutrient recycling without increasing soil or water risks, and the process was operated as zero-emission, autothermal, supporting carbon-negative performance. The design allows potential replication in integrated farm and industrial settings.

Microalgae-derived BBFs were evaluated for nutrient recovery from dairy wastewater. These treatments captured up to 74% of nitrogen and 84% of phosphorus, generating approximately 30 kg of biomass per cubic metre of wastewater. The resulting biomass can be applied as a fertiliser. Some environmental impact indicators, such as CO₂ equivalents per cubic metre of treated wastewater, were higher than conventional wastewater treatment, indicating areas for further optimisation.

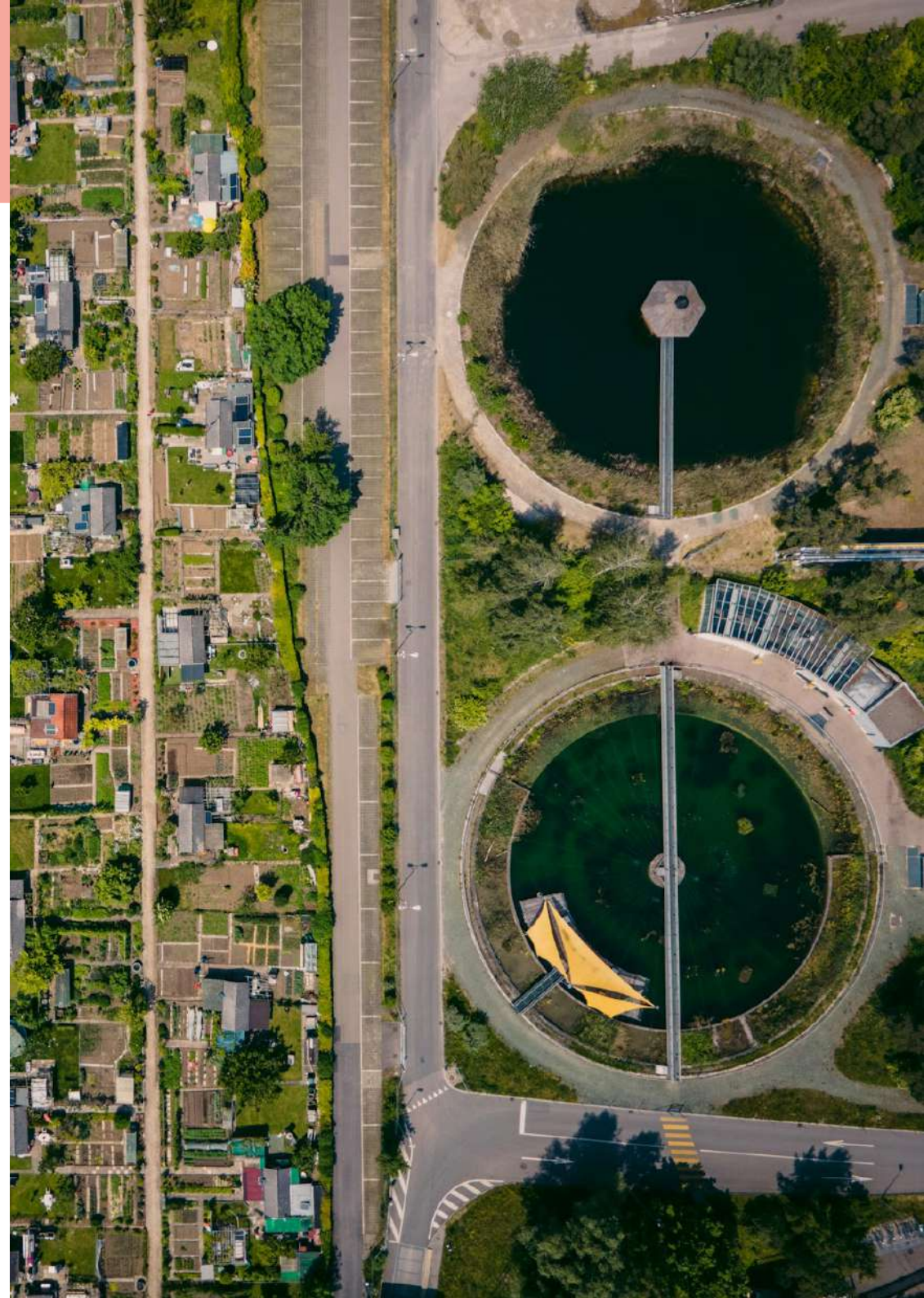
Smart BBF blend, combining recovered ammonium sulphate and struvite, provided nitrogen and phosphorus in plant-available forms. Although working with the blend as a single product proved challenging, the individual components (AS, struvite, and plant growth-promoting bacteria – PGPB) were applied as standalone products in the field trials. Results showed stable composition and practical application, supporting partial or full substitution of conventional mineral fertilisers. Environmental measurements were comparable to standard practices, and agronomic performance supported crop growth across tested systems.

At pilot scale, each 0.5 m³ batch of desalination brine processed in the WalNUT system yielded three solid products: Mg(OH)₂ with a purity of 99.3 %, CaCO₃ at 98 % purity, and KCl at approximately 94 % purity. The pilot operated in batch mode under stable process conditions, allowing reproducible recovery across runs. The recovered salts showed consistent nutrient contents: 373 g Mg kg⁻¹ (62 % MgO) for Mg(OH)₂, 364 g Ca kg⁻¹ (51 % CaO) for CaCO₃, and 480 g K kg⁻¹ (49 % K₂O) for KCl. These findings demonstrate the technical feasibility of selectively recovering high-purity macronutrient salts from desalination brine at pilot scale.

Overall, the WalNUT results demonstrate that BBFs from different production pathways can provide nutrients in forms suitable for agricultural application while supporting circular nutrient recovery. Each product exhibits distinct characteristics, and ongoing trials continue to inform their application potential, process optimisation and environmental impact.

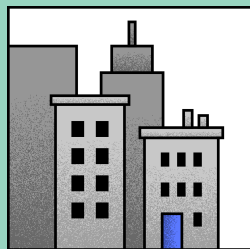
4. BBFS

This chapter presents the BBFs developed and assessed within the WaINUT project using a harmonised and common structure covering **technical description**, **practical performance**, and **SWOT analysis**. The BBFs represent different nutrient recovery pathways, product forms, and end-use applications. Together, they provide consolidated evidence on technical feasibility, agronomic effectiveness, regulatory readiness, and their potential contribution to circular, resilient, and resource-efficient fertiliser systems.



BBFS NITROGEN LOADED ZEOLITES

KIND OF WASTE: URBAN



NZ is a solid BBF evaluated in the WaINUT project, produced by recovering ammonium from wastewater through ion exchange onto a zeolite matrix. Although the total nitrogen content is low (0.14%), most of the nitrogen is present in mineral, plant-available forms and becomes available during the first cropping season. Due to this low nitrogen concentration, NZ cannot be applied as a standalone fertiliser at agronomically relevant rates. Instead, its use was considered in combination with AS and VZ to increase nitrogen content while preserving the slow-release and soil-conditioning properties of the zeolite.



Practical performance

The low nitrogen concentration of NZ limits its direct application, as supplying an agronomically relevant nitrogen dose would require excessively high application rates, for example, 108 t/ha to provide 150 kg N/ha for potatoes. To overcome this limitation, NZ was blended with AS and VZ at a ratio of 2.4:1 (VZ:AS), resulting in a product with 1.3% total N. This enabled feasible application rates of 12 t/ha for potato cultivation while maintaining the slow-release behaviour and soil-conditioning properties of the zeolite.

SWOT analysis

STRENGTHS

- ◇ High proportion of plant-available nitrogen with full mineralisation during the first season, demonstrated by safe application in vegetable pot trials
- ◇ Zeolite matrix provides potential soil-conditioning benefits

OPPORTUNITIES

- ◇ Use as a functional component in blended fertilisers such as a combination with AS
- ◇ Potential classification as inorganic soil improver or growing medium under EU FPR, if a new CMC allows wastewater-recovered zeolites to be included

WEAKNESSES

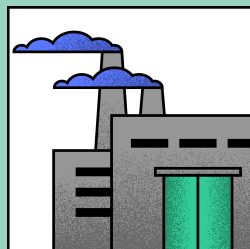
- ◇ Very low nitrogen concentration limits direct field application
- ◇ Short storage stability (up to six months) before nitrogen losses occur

THREATS

- ◇ Does not meet minimum nitrogen thresholds for EU fertiliser classification
- ◇ Agronomic performance depends strongly on blending strategy and application method

BBFS ALGAE POWDER

KIND OF WASTE: INDUSTRIAL



Algae powder is produced using nutrients recovered from dairy wastewater through a combination of photoautotrophic and heterotrophic biological processes. Production is carried out in two steps: (i) batch cultivation of photoautotrophic microalgae using light and CO₂, followed by (ii) heterotrophic treatment using wastewater as a source of carbon and nutrients. Practical performance

NZ is a solid material with very low nitrogen concentration, which limits its direct field applicability despite releasing most of its mineral nitrogen during the first crop season. In field trials, the blended AS+VZ formulation matched the performance of CAN in potatoes and showed low nitrate leaching. Pot tests confirmed no phytotoxicity and indicated that low-volume nursery applications and moderate field doses produced the best responses.

Practical performance

Algae powder functions as an organic fertiliser, with 42% of its organic nitrogen mineralised and available to crops during the first year of application. Among the treatments tested, it resulted in the highest crop dry matter yield and phosphorus uptake, as well as the lowest root biomass, indicating strong nutrient availability. It showed promising behaviour as a slow-release phosphorus fertiliser and did not negatively affect germination or cause phytotoxic effects, performing similarly to CAN fertiliser. While preliminary results indicate potential agronomic and soil-improving benefits, further agronomic and environmental assessments are required to define optimal application conditions.

SWOT analysis

STRENGTHS

- ◇ Provides access to nitrogen and phosphorus while reducing reliance on chemical fertilisers
- ◇ Creates additional revenue streams through BBF production at wastewater treatment plants

WEAKNESSES

- ◇ High investment and operating costs
- ◇ Involvement of multiple stakeholders increases system complexity

OPPORTUNITIES

- ◇ Political incentives for sustainable agriculture, with strong growth in Europe
- ◇ High circularity potential and reduced dependence on imported phosphate and nitrate

THREATS

- ◇ Restricted regulation of BBFs production
- ◇ Difficult entry into fertiliser market



BBFS BIO-NPK-C COMPOUND

KIND OF WASTE: FOOD



BIO-NPK-C is a lawfully validated bio-fertiliser product developed by 3R, delivering combined and multiple applications while generating financial values and non-financial benefits for users. User driven demonstrations made in experimental facility trials in Italy and commercial farm tests as well, which confirmed consistent yield benefits and robust crop performance under practical conditions.



Practical performance

In greenhouse tomato trials, BIO-NPK-C outperformed mineral fertilisers at an application rate of 100 kg P/ha, achieving yields up to 149 t/ha compared with 114 t/ha for mineral fertiliser and 82 t/ha for the untreated control. Nutrient release was gradual and efficient, improving nitrogen and phosphorus uptake. The product showed consistent crop response, ease of application, and robust performance under both controlled and field conditions.

SWOT analysis

STRENGTHS

- ◇ Sustainable fertiliser with feedstock-agnostic variability and high flexibility
- ◇ Lawfully certified product with regulatory approval and strong global market potential
- ◇ Cost-effective and safe
- ◇ Applications for civil, industrial, and defence purposes, high processing efficiency under zero emission

WEAKNESSES

- ◇ Currently limited to pilot scale, but ongoing preparation towards TRL9 full industrialisation
- ◇ Nutrient composition depends on feedstock quality
- ◇ Requires medium-scale capital investment at TRL9 full industrialisation
- ◇ Market uptake depends on farmer awareness of novel BBF products

OPPORTUNITIES

- ◇ Align with EU incentives and increasing demand for carbon-negative fertilisers
- ◇ Scalability and adaptability to other agri-food sectors and crops
- ◇ Integration with renewable energy and composting value chain
- ◇ Dual use and CBRN defence applications

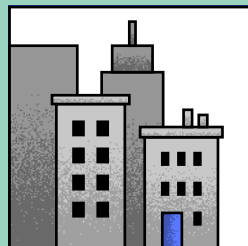
THREATS

- ◇ Competition from EU subsidised conventional fertilisers
- ◇ EU Regulatory delays and cautions farmers adoption of BBFs
- ◇ Complex geopolitical situation impacting the economy
- ◇ Competition from low-cost fertilisers imported from third countries

BBFS SMART BBF

KIND OF WASTE: SEWAGE SLUDGE

Smart BBF is produced by blending wastewater-recovered struvite, recovered ammonium sulphate (obtained via zeolite-based cation exchange and hollow-fibre membrane contactors), and PGPB.



Practical performance

Smart BBF is a liquid fertiliser with a very low nitrogen concentration, which limits its suitability for field application despite releasing most mineral nitrogen during the first cropping season. Pot trials showed no observable PGPB effect, and bacterial incorporation further diluted nutrient concentrations. As a result, PGPB were excluded from formulation and recovered struvite and ammonium sulphate blending was evaluated. CETAQUA fertiliser performed similarly to conventional fertiliser in agronomic field testing, significantly increasing maize forage yield. It can partially or fully replace conventional fertilisation, although supplementation with macro- or micronutrients may be required. While these results are statistically significant, larger-scale, multi-environment trials are recommended to confirm their applicability across diverse conditions and setting.

SWOT analysis

STRENGTHS

- ◇ Circular economy approach based on wastewater nutrient recovery
- ◇ Innovative concept integrating microbial components
- ◇ Potential for diversified revenue streams linked to WWTP operations

WEAKNESSES

- ◇ Limited shelf life due to the presence of live microorganisms
- ◇ High logistics and operational costs related to diluted products
- ◇ Low farmer awareness and requiring education and training

OPPORTUNITIES

- ◇ Growing demand for sustainable and BBFs
- ◇ Availability of public funding and policy support
- ◇ Technological advances in microbial stabilisation

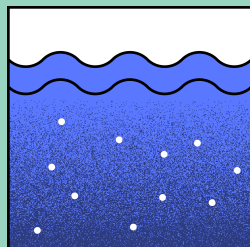
THREATS

- ◇ Competition from established synthetic and other BBFs
- ◇ Regulatory barriers for wastewater-derived products
- ◇ Market resistance linked to safety perception



BBFS RECOVERED SALTS

KIND OF WASTE: BRINE



Recovered salts are produced from brine generated during seawater desalination, where salinity increases from approximately 3.5% to about 6%. The pilot unit integrates chemical, membrane, thermal, and physical processes to recover high-purity salts, including $\text{Mg}(\text{OH})_2$, CaCO_3 , and KCl , for use within the BBF value chain.



Practical performance

Recovered salts enhanced plant growth and performed comparably to commercial fertilisers when applied at appropriate rates. Magnesium supported chlorophyll synthesis and enzyme activity, calcium improved cell wall strength, and potassium regulated osmosis and photosynthesis. In soilless systems, these salts increased biomass and reduced biotic stress without deficiency symptoms, confirming suitability for hydroponic use. However, precise dosing is critical, as excessive application can increase electrical conductivity, induce salt stress, and reduce biomass.

SWOT analysis

STRENGTHS

- ◇ Sustainable nutrient production of macronutrients from waste streams
- ◇ Reduced brine discharge and environmental impact
- ◇ Revenue generation from BBFs, recovered salts, and water
- ◇ Alignment with circular economy and EU Green Deal objectives

WEAKNESSES

- ◇ Storage, transport, and handling challenges
- ◇ Limited familiarity among end users
- ◇ High capital and operational costs
- ◇ Distribution mismatches between supply and demand

OPPORTUNITIES

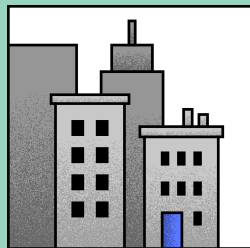
- ◇ Higher concentration of macronutrients in BBF
- ◇ Policy and financial support at EU and national levels
- ◇ Growing environmental awareness
- ◇ Continued R&D for process optimisation

THREATS

- ◇ Limited market acceptance
- ◇ Competition from conventional nutrient sources
- ◇ Regulatory and infrastructure barriers
- ◇ Uncertainty in future fertiliser policy

BBFS AMMONIUM SULPHATE

KIND OF WASTE: URBAN



AS produced within the WaINUT project is a stable, fully soluble liquid fertiliser containing 4.4% mineral nitrogen and 4.2% sulphur. It showed consistent agronomic performance in field trials, achieving yields close to CAN fertiliser and demonstrating high nitrogen efficiency.

Practical performance

Field trials showed that AS delivers first-year yields comparable to CAN, with a nitrogen fertiliser replacement value of 80-90%. Environmental monitoring indicated no increase in nitrate residues, and pot trials confirmed safe crop establishment without phytotoxic effects. Readily available nitrogen supported rapid uptake, particularly for crops with high early nitrogen demand. Under good agricultural practice conditions, nitrate leaching and ammonia emissions were comparable to CAN. Best performance is expected with row placement or injection, reducing volatilisation losses.

SWOT analysis

STRENGTHS

- ◇ Stable, fully soluble fertiliser with consistent nutrient composition
- ◇ Strong agronomic performance comparable to CAN

OPPORTUNITIES

- ◇ High readiness for integration into nutrient recovery systems
- ◇ Compatibility with fertigation and precision fertilisation

WEAKNESSES

- ◇ Risk of ammonia volatilisation if surface-applied
- ◇ Incompatibility with manure due to H₂S formation risk

THREATS

- ◇ Competition with low-cost mineral fertilisers
- ◇ Transport costs linked to concentration and location

5. WHAT WE LEARNED AND WHAT COMES NEXT

The lessons learnt during the development and validation of the WALNUT BBFs provide practical guidance for industry, farmers and researchers.

5.1 Industry perspective

Across the analysed BBFs, producers identified nutrient concentration and product stability as key factors for industrial viability. For nitrogen-based products such as AS and the AS+VZ blend, higher nitrogen concentrations are essential to reduce transport volumes and logistics costs and to enable more efficient field application. Zeolite-based products similarly require improved storage stability, as performance may decline after prolonged storage. Consistent ammonia recovery at pilot scale is also critical, as process variability directly affects fertiliser quality and market reliability (Recommendations 3 “*Economic incentives for BBFs*” and 6 “*Enhance social acceptance and technical capacity for BBFs*” of the White Paper).

Recovered salts (KCl, CaCO₃, and Mg(OH)₂) offer opportunities to diversify raw material sources and strengthen circular fertiliser value chains. Their high purity enables use as macronutrient components in blended BBFs, while KCl may also be marketed as a standalone

potassium fertiliser, reducing reliance on conventional mineral fertilisers and supporting EU fertiliser independence. The use of brine waste streams enhances circularity and economic attractiveness, and scalable recovery routes allow integration into existing fertiliser manufacturing infrastructures. Large-scale deployment will depend on consistent product quality, full compliance with the EU FPR, and reliable long-term supply.

BIO-NPK-C demonstrates a scalable and circular approach by converting food industry wastewater and biogenic residues into compound BBFs and reusable water, generating both financial and non-financial benefits. Designed for dual use in civil industrial and defence applications, it shows strong market potential supported by consistent agronomic performance, regulatory compliance, and EU recognition under REACH and Regulation (EC) No 1009/2019. Key priorities include optimising nutrient concentrations, ensuring process reproducibility, managing feedstock variability, and improving upcycling efficiency. Algae powder also presents opportunities as a sustainable wastewater treatment solution capable of generating value through BBF production.

Smart BBF shows limited potential as a standalone fertiliser due to low nutrient concentration, while recovered raw materials contain higher nutrient levels; however, neither is highly profitable in this case. Their industrial value lies primarily in integrated nitrogen management for wastewater treatment plants.

Overall, the BBFs analysed demonstrate that industrial success depends not only on agronomic performance, but also on product concentration,

stability, regulatory compliance, scalability, and integration into existing industrial systems, which are essential for market uptake and long-term competitiveness.

5.2 Farmers perspective

Field trials showed that AS and the AS+VZ blend perform comparably to conventional CAN fertiliser and can be integrated into existing fertilisation strategies. Farmers require clear and practical guidance to ensure safe and efficient use, including avoiding mixing AS with manure due to hydrogen sulphide risks and preferring placement or injection methods to reduce ammonia losses. Zeolite-based materials were generally easy to handle, requiring only basic dust protection during application.

Recovered salts were perceived by farmers as valuable alternative nutrient sources supporting sustainable farming. Potassium and magnesium salts improved crop nutrition, while calcium carbonate supported soil pH regulation and structural improvement. When incorporated into blended BBFs, they allow tailored fertilisation adapted to specific soil and crop needs. Farmers' acceptance depends on agronomic performance, ease of application, price competitiveness, and regulatory assurance.

Commercial trials with BIO-NPK-C confirmed its safe, lawful, and cost-effective integration into standard farming practices. Farmers reported stable nutrient availability, supporting crop growth while reducing reliance on mineral fertilisers. The high bioavailable phosphorus and calcium content, free from toxic metal contamination, was particularly

valued in soils with low natural fertility. Dry storage was identified as essential to maintain nutrient stability and prevent caking.

Trials with Smart BBF demonstrated its potential to partially or fully replace mineral fertilisers in crops such as maize and cabbage, providing a viable alternative source of nitrogen and phosphorus within conventional farming systems.

Overall, farmers emphasised that successful adoption of BBFs depends on reliable agronomic performance, clear application guidance, compatibility with existing equipment, regulatory compliance, and competitive pricing. These practical recommendations could be integrated into dedicated BBF training modules and advisory curricula (Recommendation 6 “*Enhance social acceptance and technical capacity for BBFs*”).

5.3 Researchers' perspective

Researchers stress the importance of multi-year and multi-site datasets to validate the long-term agronomic performance and environmental behaviour of BBFs. While early results are positive, particularly for AS and the AS+VZ blend, continued monitoring is required to assess impacts on soil quality, nutrient cycling, and emissions. Several BBFs within the WalNUT portfolio still require complete agronomic and environmental evaluation, and future assessments should prioritise harmonised methodologies to ensure comparability across sites and products. This is directly supported by Recommendation 5 “*Support long-term agronomic validation*”).

Recovered salts represent a significant research opportunity encompassing process optimisation, product development, and environmental assessment. Further studies are needed to evaluate their long-term agronomic performance across diverse soil types and climatic conditions. Researchers also play a critical role in generating the scientific evidence required for regulatory approval, including pollutant characterisation and life-cycle sustainability assessments. Integrating recovered salts into BBF formulations provides an interdisciplinary research platform linking desalination technologies, nutrient recovery, fertiliser science, and circular-economy policy frameworks.

For BIO-NPK-C, researchers emphasise the need for extended, multi-season field trials to confirm long-term effects on crop performance, soil structure, nutrient dynamics, and greenhouse gas emissions. Although early observations from commercial trials indicate positive outcomes in nutrient availability, crop growth, and soil health, further industrial-scale research is required to assess different formulations and application rates across varying soils and climatic zones.

Overall, researchers highlight that long-term field validation, standardisation of methodologies, and integration of agronomic, environmental, and process-level research are essential to confirm regional performance, sustainability benefits, and global applicability of BBFs, in line with Recommendation 5 “Support long-term agronomic validation”.

5.4 The value of collaboration and data sharing

Collaboration between wastewater operators, fertiliser producers, agronomic researchers, and agricultural advisors proved highly valuable for aligning methodologies and ensuring robust data generation. The use of shared datasets and harmonised analytical procedures reduced uncertainty and enabled more consistent and comparable assessments across products and sites. Continued collaboration will remain essential as the project progresses and additional BBFs reach higher levels of maturity. Recommendations 2 “European BBFs observatory” and 6 “*Enhance social acceptance and technical capacity for BBFs*” of the White Paper “*Green growth: from waste to bio-based fertilisers*”) further outline the role of the Observatory and Collaboration Hubs as key structural enablers of this process.

6. CONCLUSIONS

The WaLNUT project demonstrates that BBFs recovered from wastewater can provide agronomic performance comparable to conventional mineral fertilisers while supporting circular nutrient management.

Among the products assessed, **AS** and the **AS+VZ blend** showed the highest level of technical and agronomic maturity, delivering yields comparable to CAN and nitrogen fertiliser replacement values of approximately 80-90% and 65-90%, respectively. Environmental monitoring under the tested conditions indicated no increase in nitrate residues or significant changes in N₂O or CO₂ emissions. The **NZ**, although not suitable as a standalone fertiliser due to its low nitrogen content, adds value when **blended with AS+VZ** by providing slow-release and soil-conditioning benefits.

The **Smart BBF** demonstrated effective nitrogen and phosphorus recovery, showing potential as a complementary nutrient source within conventional fertilisation systems. **Recovered salts** (KCl, CaCO₃, Mg(OH)₂) were identified as practical alternatives or supplements to mineral fertilisers, contributing to crop nutrition, soil health, and tailored fertiliser formulations. **BIO-NPK-C** was successfully applied in trials, providing stable nutrient availability, supporting soil health, and demonstrating integration with conventional fertilisation practices, while aligning with circular economy principles.

Overall, the project shows that BBFs recovered from wastewater can contribute to reducing dependence on imported mineral fertilisers, improving nutrient recovery, and establishing regional circular nutrient loops. Their successful integration into agricultural practice depends on continued optimisation, standardised application guidance, regulatory alignment, and engagement with farmers and industry stakeholders.



WALNUT

Waste water is not wasted



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