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Boosting synergies between water and agriculture sectors

Layman's Report

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AIGÜES DEL SEGARRA GARRIGUES, SA ASG

Life

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The LIFE ENRICH project started in September 2017 and ended in November 2021. The total budget for the project was **2.7M€**, from where around the 60% of the budget was co-funded by the **LIFE programme** of the European Commission. Cetaqua (Water Technology Centre) led the project and counted with EMUASA, UPC, UPV, IRTA and ASG as partners.

Project partners

Cetaqua is a model of public-private collaboration that was created to ensure the sustainability and efficiency of the water cycle while taking regional needs into account.

IRTA is a public research institution, part of the Department of Agriculture, Livestock, Fisheries, Food and Environment of the Government of Catalonia. IRTA's mission is to contribute to modernising, improving, boosting competitiveness, and fostering sustainable development in the agrifood sector.

The **Universitat Politècnica de Catalunya (UPC)** is a public institution dedicated to higher education and research, specialized in the fields of engineering, architecture and science. The UPC puts its scientific and technological infrastructure at the service of research groups and centers, researchers and students, professionals, companies and institutions.

The **Universitat Politècnica de València (UPV)** is a public, dynamic, and innovative institution that educates people in order to enhance their skills; researches and generates knowledge, with the assurance of quality, rigor and ethics, in the fields of science, technology, art and business.

Aguas de Murcia (EMUASA) is a joint venture service company, 51% owned by the City of Murcia and 49% owned by HIDROGEA, that manages the water cycle in the municipality of Murcia, serving nearly 445,086 people divided between the urban centre, the surrounding countryside and 54 villages.

Aigües del Segarra Garrigues is a private company with an expertise in fertilizing and irrigation systems which mission is to execute land consolidation projects, drafting of projects, execution of works and exploitation of the system distribution network Segarra Garrigues irrigation.

Skateholders

LIFE ENRICH stakeholders played an important role in the development of the project, participating in different ways, as well as giving technical support to the project consortium.

Towards a circular resource management: nutrient recovery and reuse is a double win

Nowadays, the wastewater treatment sector and the agricultural sector are independent one to another. In the agricultural sector, **phosphorus and nitrogen** are main nutrients used in fertilizers. However, the production of nitrogen-based fertilizers for use in agriculture has a negative impact on the environment due to its high energy consumption. On the other hand, phosphorus is a non-renewable natural resource, so if the current levels of exploitation are maintained, it may become scarce in the future.

Regarding wastewater treatment plants (WWTPs), they remove, among other nutrients, the nitrogen and phosphorus present in the wastewater to prevent the pollutions that the treated water can cause in the natural environment. Specifically, during this purification process, **nitrogen is biologically converted to nitrogen gas**, while **phosphorus is removed from the water by chemical precipitation** in most cases, which carries into high operating costs.

The LIFE ENRICH project targets several environmental problems, related to the steps of the process from the recovery of raw materials (upstream) to the creation of a final product and its use for agricultural activities (downstream). The most relevant **environmental problems targeted in the project** are:

1. Depletion of phosphate rock reserves

Phosphorus is an essential nutrient for life and indispensable for agriculture. Modern agriculture is dependent on phosphorus mining derived from high-grade phosphate rock, which is a non-renewable resource. It is an essential, limited and strategic resource, and known reserves' depletion is predicted in 50-100 years (depending on the source). Phosphorus recovery from WWTPs for agricultural purposes is thus a way to mitigate the environmental problem linked to food demand satisfaction.

2. Carbon footprint of production and use of chemical fertilizers

Using fertilizers recovered from wastewater at WWTPs, like the struvite and other nitrogen-based fertilizers, could help **reduce the emissions related to agricultural activities**. A shift towards fertilizer production from organic or secondary raw materials would also reduce CO_2 emissions, hence contributing towards a low carbon economy and the sustainability of the fertilizers sector (European Circular Economy Action Plan, Regulation EU 2019/1009).

3. Carbon footprint of the N removal processes in WWTPs

A big portion of carbon footprint from the WWTPs comes from indirect emissions of CO_2, caused by the intensive energy consumption. The integration of alternative processes for the nitrogen recovery could have a positive impact on the WWTPs' carbon footprint by **reducing the direct and indirect emissions resulting of the secondary biological treatment process**, to contribute to the achievement of the Water Framework Directive requirements, including the Urban Wastewater Treatment Directive (91/271/EEC).

4. Eutrophication

Eutrophication is the enrichment of water because of an increase in nutrients, which have a negative impact on the marine and coastal environment. **The ineffective treatment of the effluents generated in wastewater treatment plants can contribute to eutrophication phenomena** due to their high content in nutrients. Stringent limits for nitrogen and phosphorus discharges in WWTP are already required in some countries.

5. Sewage sludge management

Considering the large amount of sludge generated in the different EU countries, it is essential to increase the recirculation of nutrients in our society. In this regard, **controlled struvite precipitation leads to an improvement in dewaterability of the digested sludge**, which eventually leads to lower volumes of dewatered sludge that need to be disposed. LIFE ENRICH also promotes the agricultural use of sewage sludge, according to the Waste Framework Directive (2008/98/EC).

Boosting synergies between water and agriculture sectors

The LIFE ENRICH project proposes a solution that allows the recovery of nutrients from wastewater and their use as fertilizers. The recovered nutrients have been analyzed in detail and mixed to obtain optimum products for their use in certain crops, **thus promoting a circular economy model**.

The project **also analyzes the entire value chain of nutrient recycling**, integrating fertilizer industry and farmers, public administration and platforms, wastewater treatment plants, universities and technology centers, with the aim of **demonstrating the technical, economic, environmental and regulatory feasibility of this new value chain**. In a second stage, the replicability of this initiative to other European countries has been evaluated.

LIFE ENRICH tackles this value chain by developing a new treatment train that has been designed, built and operated in an urban WWTP. The products obtained have been mixed in order to find optimal mixtures and the agronomic properties of these products have been validated at full-scale through field tests in order to ensure the viability of the products obtained.

LIFE ENRICH deals with the whole value chain: the recovery of nutrients in the WWTP, the characterization and optimal mixing of them to obtain added-value fertilizers and the validation of its performance in a real case study (end-user). Moreover, the appropriate business model has been designed in parallel in order to ensure that the proposed solution is ready to be transferred and replicated in other sites/regions.

Specific objectives are:

- **Define the business model for the entire nutrient recycling value chain**, integrating nutrient producers and final end-users, and propose a business plan for Spain.
- **Assess the replicability of the business model to other European countries** apart from Spain (Denmark, Italy and Netherland), considering technical, economic and environmental issues, as well as the legal framework in each particular case.
- **Validate a treatment train integrating different technologies** for the recovery of both nitrogen and phosphorus from wastewater in existing WWTPs.
- **Increase the efficiency of P recovery by implementing new elutriation schemes for enhanced recovery. Maximize struvite production and contribute to its regulation and commercialization under fertilizer directives and regulations.**
- **Develop membrane contactors technology to produce ammonium salts** and contribute to its regulation and commercialization under fertilizer directives (proposal for specifications).
- **Define the optimal fertilizer mixtures for crops of interest** and demonstration of the agronomic properties of the recovered products.
- **Promote the agronomic value of sewage sludge as a source of nutrients** (N and P) and organic carbon.

LIFE ENRICH technology and fertilizing trials

Nutrient recovery from wastewater

One of the innovative aspects of the project is the integration of different technologies for N and P recovery in only one site. **Murcia Este WWTP (Murcia, Spain) was the experimental site** selected to demonstrate this integrated P&N recovery process. First, an elutriation process full-scale was implemented, in a reversible configuration, in order to extract and concentrate phosphates before they enter anaerobic digestion, were uncontrolled P precipitation starts causing operational problems. Phosphates concentrate in the supernatant of primary thickeners can feed the P recovery unit for struvite production.

P and N recovery units were tested at pilot scale. Depending on the configuration of the WWTP, phosphate can accumulate in centrates or in the supernatant from primary thickeners, so both streams were fed to the P recovery unit, where ammonium accumulates in higher concentrations, allowing struvite production. N recovery was assessed in centrates stream, since it accumulates ammonium in high concentrations allowing high N recovery rates. Altogether, LIFE ENRICH integrated P&N recovery solution (see Figure 1) enables **a flexible and robust process that maximizes nutrient recovery**. Moreover, LIFE ENRICH fertilizing products as struvite, ammonium nitrate and sludge, were used in crop trials to assess their suitability as fertilizers compared with conventional fertilizers.

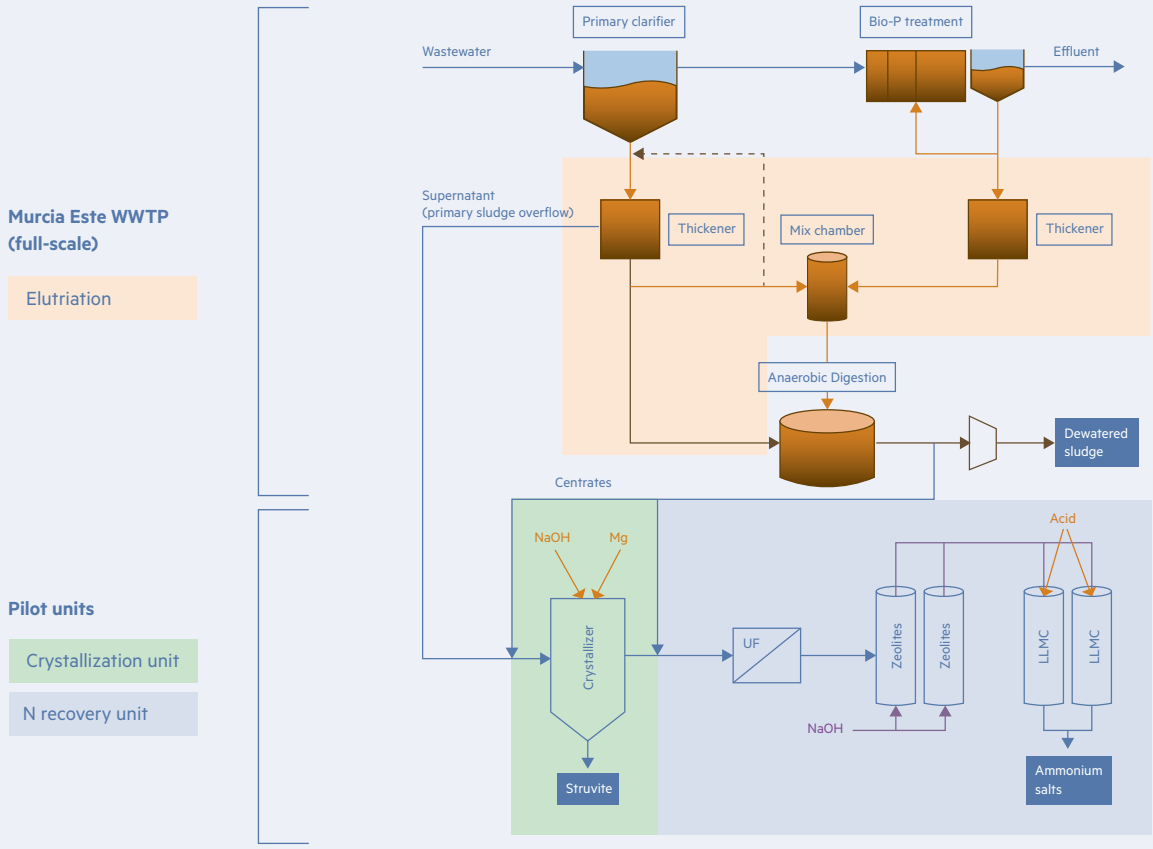

Figure 1. Murcia Este WWTP process configuration with ENRICH solution

Field trials with LIFE ENRICH fertilizers

The recovered struvite and ammonium nitrate (AN) obtained from the prototype were characterized to accomplish the legislative requirements for new fertilizing materials (EU 2019/1009).

Therefore, **the new fertilizers were used as raw materials for the manufacture of the optimal nutrient solution (NS) for fertigation (injection of water-soluble fertilizers into the irrigation system) of three horticultural crop species**.

Three different compositions of NS were tested, differing on the P and N sources:

1. Struvite. With 100% and 17±2% of P and N recovered source, respectively.

2. Struvite and ammonium nitrate. With 100% and 34±6% of P and N recovered source, respectively.

3. The conventional (CON) fertilization using solely synthetic fertilizers. The recovered sources were the P and N from ground struvite and the $N\text{-}NH_4^+$ from liquid AN. The reference P fertilizer used in the CON nutrient solution was $KH2PO_4$. Other commercial fertilizers were used to complete the NS and to lower the pH.

The fertigation system was established by 2 tanks per treatment, containing concentrated nutrient solution x100 (cNS) to be released into passing irrigation water through venturi system with automatic control of irrigation. There were two field trial conditions, one in Cabrils under greenhouse-controlled conditions in two different growing media, perlite as soilless trial and soil. The second in Lleida (Agramunt and Castelldans) at open-air conditions, both in Catalonia-Spain. Additionally, struvite dissolution tests were performed to ensure its solubility. Satisfactory results of struvite solubilization were obtained promoting its use as a soluble mixed fertilizer. Particularly, struvite has not been implemented in fertigation as the unique source of P fertilizer so far.

Figure 2. Sample of struvite produced

Figure 3. Broccoli crops at IRTA facilities

The results of the agronomic assays revealed **that struvite and ammonium nitrate used as fertilizers in fertigation systems for tomato, broccoli, cauliflower and lettuce crops were equally effective** in total yield (fresh or dry matter) and quality product to conventional fertilizers, both in the greenhouse and open-air conditions. Yet, it is important to consider the ammonium tolerance of the plant species and variety. For the first time, struvite has been used in fertigation in edible crops and this use has been fully successful. Even so, the irrigation water composition must be considered due to its function as buffering solution.

Furthermore, results confirm that **more sustainable fertilization management for soilless tomato cultivation under Mediterranean climatic conditions was achieved**. The nitrogen concentration of the nutrient solution has been adjusted to a lower concentration than the one normally used and depending on the phenological stage of the crop (5-8-5 meq-N/L), without reducing yield or physical quality, which may cause the reduction of N leaching and its environmental impact on the water bodies.

Moreover, two arable crops campaigns, with barley, beans and oats crops were done in Lleida to use the dewatered sludge as a soil conditioner. The dewatered sewage sludge tested exhibited no differences in the production of the arable crops compared to commercial fertilizer. However, it should be noted that the low nutritional richness of the sludge applied makes it necessary to transport a big volume to achieve fertilization needs, therefore, transport distance from the treatment plant to the point of application should be considered. **The competitiveness of sewage sludge can be improved by increasing its nutrient richness**, and this could be done by adding struvite, which we have found is an interesting fertilizer for agriculture.

These results give insight into the **urgent need for more sustainable crop management reducing the fertilizer demand and boosting circularity in horticulture**.

LIFE ENRICH value chain

Technical, environmental and economic assessment of LIFE ENRICH value chain

The **technical efficiency, the environmental impact and the economic feasibility** of the LIFE ENRICH value chain (nutrients recovery and valorization in agriculture) were assessed for a full-scale process implementation in Murcia Este WWTP and through the LCA (Life Cycle Analysis) and LCC (Life Cycle Cost) methodologies. **A comparison between the current situation (conventional scenario) and LIFE ENRICH scenario (P&N recovery) was performed** within a defined framework that involves WWTP operation, not only nutrient recovery but the whole installation, and field fertilization, considering recovered nutrients P and N and also K and Ca macronutrients present in most used conventional fertilizers.

A full-scale nutrient recovery LIFE ENRICH process was assessed for this study, considering a favorable scenario for bio-P removal within the Murcia Este current sludge line configuration that includes elutriation. For P recovery, the phosphates come from the supernatant of primary thickeners, while ammonium in excess is coming from both supernatant and centrates. N recovery is placed after P recovery unit to maximize ammonium recovery.

Murcia Este WWTP showed a great potential for nutrient recovery suitable for fertilization with positive economic and environmental impacts for both WWTP and cropland. These are encouraging results for the implementation of LIFE ENRICH value chain.

A LCI (Life Cycle Inventory) was performed to detail all inputs and outputs in WWTP and in the field regarding 2 scenarios studied (conventional and N&P ENRICH), including consumptions, production volumes and pricings, obtained from WWTP dataset, WWTP characterization, technologies validation and crop trials.

Murcia Este full-scale projection will produce 1100 t/y of struvite and 1937 t/y of ammonium nitrate (21%w), which accounts for 42% of P recovery and 11% of N recovery (8.4% as AN) of total P and N present in wastewater influent, under a favorable scenario of high bio-P removal and 9.1 mg/L of P_{tot} in WWTP influent. Considering market prices of 350 and 410 €/t of struvite and AN, revenues would be of 385 k€/y and 794 k€/y, respectively (total of 1.17 M€). The estimated CAPEX will be of 4.76 M€ for struvite production (75 k€ for elutriation process) and 1.39 M€ for AN production (total of 6.15 M€). Regarding operational costs of nutrient recovery technologies, OPEX for struvite production is 202 k€/y (183 €/t) and for AN, 891 k€/y (460 €/t), being the main costs NHO_3 and zeolites (N recovery) and NaOH (P recovery) over other chemicals and energy consumption.

Also, LIFE ENRICH nutrient recovery process has other benefits regarding WWTP performance, which translate in **OPEX savings for the installation**. They come from improving sludge dewaterability, avoiding uncontrolled P precipitation problems, and reduce the nitrogen load to biological reactors. Results pointed out that, at full-scale for maximize P&N recovery, Murcia Este WWTP would benefit from savings of 7.4% in aeration requirements (nitrification) (31k€/y), 17.9% in dewatering energy consumption (8k€/y), 27% in polymer requirement for dewatering (52 k€/y), 20% in sludge management (119 k€/y), 85% in antiscaling and maintenance due to uncontrolled P precipitation (11k€/ and 14 k€/y respectively). This is a total savings of 235 k€/y. Overall, a positive margin of 322 k€/y would be achieved.

Regarding the **environmental impact** of LIFE ENRICH process implementation, a surface of 29,572 m2 was considered to be fertilized using tomato crops as reference for soil nutrient requirements. Struvite and AN were considered in substitution of conventional fertilizers for P and N source MAP and AN fertilizers for P and N source, while potassium sulfate and calcium nitrate were considered for K and Ca balancing. Key environmental indicators studied show a significant reduction when using alternative LIFE ENRICH fertilizer of 20% in CO^2 eq emissions (from energy and chemical consumption) and 58% in mineral resource scarcity as Cu eq emissions (mainly from the recycling of P source).

Murcia Este WWTP showed a great potential for nutrient recovery suitable for fertilization with positive economic and environmental impacts for both WWTP and cropland. These are encouraging results for the implementation of LIFE ENRICH value chain.

LIFE ENRICH Business Plan

Introduction

A business Plan for LIFE ENRICH value chain implementation in Spain was defined. As part of the Business Plan, a market analysis was performed regarding fertilizer industry, 2 business models were developed, a SWOT analysis was performed on the whole LIFE ENRICH value chain and the financial projections were determined. **The Business Plan will lead the steps to make nutrient recovery as fertilizers in Spain a reality**.

The market analysis highlighted a great fertilizer market, with a total capacity production of 6,000 kt/year (2018) of which complex fertilizers (as MAP) account for 31.3% of the total while ammonium nitrate, for 19.1%. Regarding production capacity of LIFE ENRICH fertilizers in Spain, it was estimated that the market share would be of 0.6% for struvite (34 kt/y) and 1.2% for AN (73 kt/y), with room for alternative fertilizers entering the market. Also, market trends from World Bank estimates that, for 2029, MAP price could be higher that struvite price of 350 €/t, while alternative AN price would be still higher that the AN price, but only a 17% higher.

The fact that end-users are willing to incorporate alternative fertilizing products is also a push factor for WWTP to implement nutrient recovery technologies such as LIFE ENRICH as they rely on selling for a positive economic balance of the process.

The identification and feedback on LIFE ENRICH value chain of key players in Spanish market revealed useful insight on business model and plan definition and expectations. The incorporation of struvite as fertilizer in the new EU Fertilizer Products regulation (2019/1009 CE) that will come into force in July 2022

is a major incentive for both fertilizer industry and farming sector to accept alternative fertilizers, not only struvite but AN too. **Alternative fertilizers are perceived as a positive incorporation** not only from an environmental point of view, but also as potential key element to cope with new agriculture and fertilizing policies, practices and taxes aimed to reduce environmental impact and preserve soil quality. Nevertheless, with no current mandatory use on alternative fertilizers nor economic incentives associated, matching prices between alternative and conventional ones is a end-users request.

The fact that **end-users are willing to incorporate alternative fertilizing products** is also a push factor for WWTP to implement nutrient recovery technologies such as LIFE ENRICH as they rely on selling for a positive economic balance of the process. Nevertheless, initial investment is hardly affordable for WWTPs so administration involvement to financing LIFE ENRICH nutrient recovery process is required.

For the implementation of LIFE ENRICH value chain 2 business models were developed following CANVAS strategic management tool, one for the commercialization of the LIFE ENRICH technology, suitable for engineering companies, and one for the commercialization of LIFE ENRICH fertilizers, suitable for WWTP operators (see figures 10 and 11). The value proposition, customer target and engagement, as well as key activities, partners and resources were defined, along with cost structure and revenue streams.

Regarding **financial projections**, for WWTP implementation of technology it has been considered public administration funding to implement the process, so operators would obtain benefits from year one regarding nutrient recovery LIFE ENRICH process and fertilizer selling, as the economic assessment determined. Regarding the engineering company in charge of LIFE ENRICH process design and implementation for P&N recovery as struvite and AN, **it has been estimated that in 5 years 8 WWTP will have implemented the technological solution in Spain**. Also, turnkey projects with 1 year of execution has been considered as the selling strategy, thus, revenues are expected from year 1 after finishing first turnkey installation. Moreover, a patent has been registered by Cetaqua including LIFE ENRICH P&N recovery technological train; thus, allowing the exploitation of results through the Spanish Business Plan.

The SWOT analysis reflected all the inputs and insight from different value chain key actors, highlighting as strengths the positive environmental impact of LIFE ENRICH solution in WWTPs and cropland and OPEX reduction in WWTPs from process enhancing and fertilizers selling, while potential not competitive fertilizer pricing and typical slow legal framework adaptation would be the main weaknesses/threats. On the contrary, new environmental and circular economy policies concerning both fertilizers and wastewater are opportunities to strengthen the business.

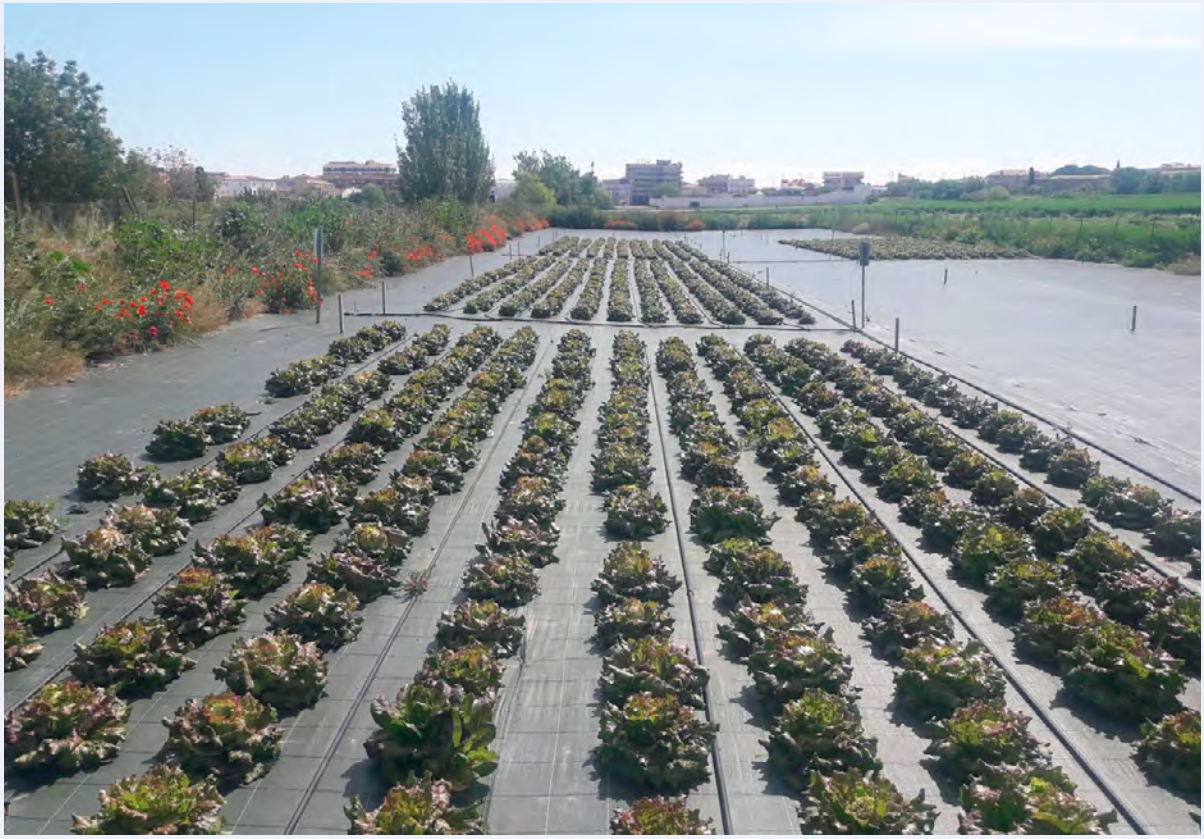

Figure 4. Lettuce crop at Agramunt

LIFE ENRICH replicability & transferability

Replicability of LIFE ENRICH solution was assessed in 3 WWTPs with different casuistic, showing the flexibility and potential of LIFE ENRICH solution and value chain:

- **Baix Llobregat WWTP** (2,000,000 PE) is one of the biggest WWTP in Spain and a reference for WWTP transition to Biofactories; it presents a high P&N recovery potential following the same configuration as Murcia Este WWTP. Replicability study showed a potential alternative fertilizer production of 1806 t/y of struvite and 2816 t/y of AN, with a total CAPEX of 9 M€, and an OPEX of 1.6M€/y.

- **Cabezo Beaza WWTP** (380,000 PE) is a WWTP with high biological P removal that concentrates phosphates and ammonium in the dewatering centrates, thus, P&N recovery train are implemented in series in this stream. Replicability study showed a potential alternative fertilizer production of 247 t/y of struvite and 311 t/y of AN, with a total CAPEX of 413 k€, and an OPEX of 146 k€/y.

- **Alt Maresme Nord WWTP** (245,000 PE) is a WWTP that operates a sludge treatment platform (anaerobic digestion with biogas production) that manages sludge produced onsite along with those of other 5 surrounding WWTPs. In this process configuration, P recovery after elutriation is performed in external sludge, avoiding serious uncontrolled P precipitation problems. N recovery takes place from centrates stream. Replicability study showed a potential alternative fertilizer production of 92 t/y of struvite and 1183 t/y of AN, with a total CAPEX of 1.1 M€, and an OPEX of 468 k€/y.

General guidelines regarding technical assessment for LIFE ENRICH process implementation as well as operation were defined with the objective of select the best process configuration and optimize nutrient recovery minimizing operational risks.

Transferability of LIFE ENRICH value chain was also assessed in 3 European countries apart from Spain. The countries were selected based on different criteria and a potential market for technology implementation and fertilizers commercialization was determined. Business model adaptation was performed based on each country particular context:

- **Italy** accounts for **3,034 WWTPs**, susceptible to implement LIFE ENRICH solution. Sludge production and sludge management costs are among the highest in EU, thus, WWTPs will benefit from implementing LIFE ENRICH process regarding sludge production reduction and its potential application to agriculture. Also, Italy has a high P&N **consumption, of 529 kt N and 118 kt P** per year, which offers great market opportunity for the incorporation of alternative fertilizers.

- **Denmark** accounts for **377 WWTPs**, susceptible to implement LIFE ENRICH solution. Also, 3 full-scale struvite production crystallization units are operating with the technology assessed in LIFE ENRICH, thus, integrated P&N recovery will have a faster acceptance. Also, Denmark has national approval to commercialize struvite, so it is expected a faster incorporation and market-share growth for alternative fertilizers. Denmark is the 7th EU country in specific fertilizer consumption, reaching a total fertilizer **consumption of 252 kt N and 20.8 kt P** per year.

- **Netherland** accounts for **360 WWTPs**, with several facilities recovering P and also national approval for struvite commercialization. Netherland is 1st specific fertilizer consumer country in the EU, being the potential market for alternative fertilizers of **207 kt N and 6 kt P per year**. In this case, fertilizer industry is also commited with sustainable fertilizers production, since ICL production site, one of the main fertilizer production facilities in Europe, already incorporates struvite as secondary raw material for fertilizers production. The end-users and administration commitment with alternative fertilizer use will pull the implementation of LIFE ENRICH value chain.

The feasibility of replicability and transferability of LIFE ENRICH value chain has been demonstrated, showing that LIFE ENRICH solution helps WWTPs, fertilizer industry and farmers across countries with different contexts to implement nutrient recovery strategies that benefits water and agriculture sectors from both an economic and environmental perspective.

Final conclusions

Innovation is the key to a sustainable future. A future that can only be circular. LIFE ENRICH has demonstrated an efficient, sustainable, replicable and transferable value chain that boosts synergies between water and agriculture, two sectors that have been independent one to another until now. **A significant step forward in wastewater management and sustainable agriculture.**

Specifically, the LIFE ENRICH project has proposed a solution that allows the **recovery of nutrients from wastewater** and their **use as fertilizers**. Murcia Este WWTP full-scale assessment showed a potential recovery up to **42% of phosphorus** and up to **11% of nitrogen** of the WWTP influent along with a **N_2O emissions reduction of 11%** by minimizing the nitrogen load to biological reactors. As a result, analysis showed that **it is possible to produce a high-quality struvite** in compliance with the EU Fertilizers Products Regulation (2019/1009 CE) and meeting TOC, metal and pathogens limits and ammonium nitrate free of metals and organic micropollutants.

The recovered nutrients have been analyzed in detail and mixed to obtain optimum products for their use in main horticultural and arable crops in Spain and Europe. The results of the full-scale agronomic assays have revealed **that struvite and ammonium nitrate used as fertilizers in fertigation systems for tomato, broccoli, cauliflower and lettuce crops were equally effective** in total yield (fresh or dry matter) and quality product to conventional fertilizers, both in the greenhouse and open-air conditions. For the first time, struvite has been used in fertigation in edible crops and this use has been fully successful. Furthermore, results confirm that **more sustainable fertilization management for soilless tomato cultivation under Mediterranean climatic conditions was achieved**. The use of the fertilizers produced by the LIFE ENRICH process **has reduced by 80% the emissions of CO_2 associated to energy consumption in conventional N fertilizers production**. Moreover, dewatered sewage sluge open-air trials in barley, beans and oats crops exhibited no differences in the production of the arable crops compared to commercial fertilizer, thus, encouraging its agricultural use.

The LIFE ENRICH project **has also analyzed the entire value chain of nutrient recycling**, integrating fertilizer industry and farmers, public administration and platforms, wastewater treatment plants, universities and technology centers, with the aim of **demonstrating the technical, economic, environmental and regulatory feasibility of the new business models developed**. In the economic perspective, the LIFE ENRICH process allows to reduce the OPEX of the WWTP by 3.3%.

The LIFE ENRICH solution is now ready to be replicated and transferred. The fact that **end-users are willing to incorporate alternative fertilizing products** is also a push factor for WWTPs to implement nutrient recovery technologies such as LIFE ENRICH, as well as the incorporation of struvite as fertilizer in the new EU Fertilizer Products regulation (2019/1009 CE) is a major step for the transition towards a sustainable and circular economy-based nutrient management system.

The feasibility of replicability and transferability of LIFE ENRICH value chain has been demonstrated, showing that LIFE ENRICH solution suits different territorial needs and contexts, helping WWTPs, and fertilizer producers and consumers to implement circular nutrient recovery strategies that benefits both sectors from an economic and environmental perpective.

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