Flemish biobased fertilizers recovered from manure complying to the RENURE-criteria

December 2020

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BTW nummer: BE 0860.082.370

1 Content

2 Summary

As part of the realization of a circular manure processing, and awaiting the translation of the SAFEMANURE findings into an European and Flemish policy framework, VCM would like to inform the European Commission on RENURE-products (ammonium salts, mineral concentrates and liquid fraction of digestate) being produced in Flanders, as well as the currently available information on the technologies producing these products, the characteristics of these products, the environmental impact of the application of these products and the currently relevant Flemish/European legislation.

The Flemish government is taking steps for rapid implementation of the policy framework on the application of RENURE-products as replacement for chemical fertilisers, as soon as it is clearly defined by the European Commission. At least 18 Flemish pioneers (livestock farmers and constructors) are awaiting this policy framework.

A clear policy framework could further stimulate innovation and a sustainable implementation as, once RENURE can be applied as replacement for chemical fertilizers, the 'early majority' will become persuaded to invest in new technologies (stripping-scrubbing/membrane filtration) on their plant, and/or to adapt their current operation practices (such as separation technologies) to produce products complying to the RENURE criteria.

The criteria for safe use of RENURE as replacement for mineral fertilizers are well known and investigated. Further research should focus on the sustainable implementation of the policy framework being developed by the European Commission on the application of RENURE. Therefore, in Flanders, VCM is currently searching funding, together with representatives of knowledge centres and coordination centres from from regions with a high nutrient pressure such as The Netherlands, Spain (Catalonia), Italy (Lombardy), France (Brittany), Malta and members of the Baltic Sea Region, for pilot projects to facilitate the sustainable implementation of the policy framework into practice. These pilots can collect information to help the member state governments develop measurements to reinforce the sustainable application of RENURE based on good agricultural management practices, within their territory. During such project, special attention will also be paid to the opportunities to efficiently use the other streams resulting from nitrogen recovery (organic solid fraction, a nitrogen-poor effluent, permeate of filtration processes,…).

VCM is available to provide further explanation on the content of this document during a consultation with representatives of the European Commission.

3 Background

3.1 Transition of towards a circular economy

At European level, the evolution to a **circular economy** is high on the policy agenda. The European Commission has adopted a new Circular Economy Action Plan - one of the main blocks of the European Green Deal, Europe's new agenda for sustainable growth. The Farm to Fork Strategy is at the heart of this European Green Deal aiming to make food systems fair, healthy and environmentally friendly. One of the ambitious targets set by this strategy is zero pollution from nitrogen and phosphorus flows from fertilisers through reducing nutrient losses by at least 50%, while ensuring that there is no deterioration in soil fertility. This will result in the reduction of use of fertilisers by at least 20%.

Therefore, the evolution towards a Circular Economy also influences the manure processing sector in Flanders and in other regions such as The Netherlands, Brittany (France), Catalonia (Spain), Lombardy (Italy), Germany, Malta and the Baltic Sea Region, including Denmark and Finland. With innovative techniques that recover nutrients from animal manure and other biomass into mineral fertilisers and a range of organic fertilisers/soil improvers, the agricultural sector is offered the opportunity to recycle nutrients, organic matter and water and to use alternatives to conventional chemical fertilisers tailored to the principles of the Circular Economy.

The realization of a transition in de manure processing sector towards a circular economy in Flanders asks efforts from both the government as well as the sector. Therefore, VCM vzw founded in 2016 the VCM workgroup 'Transition in manure processing' to discuss the ideal transition towards a circular economy and the way to increase the sustainability of the manure processing sector in Flanders. From discussions and brainstorm sessions in the context of this workgroup, a vision statement grew[1].

In this statement, VCM emphasizes that a transition of the manure processing towards a circular economy, by means of nutrient – and resource recuperation, can result in:

- a replacement of mineral (chemical) fertilizers by manure processing products;
- a reduction of the import of non-renewable resources such as phosphate rock;
- the production of resources (proteins, fibers,…) from manure;
- the valorisation of organic carbon from manure on Flemish agricultural fields.

Besides, additional sustainability criteria related to water, soil and air quality and carbon footprint, can be coupled to this transition.

[1] The VCM vision note (in Dutch) can be found here: https://www.vcm-mestverwerking.be/nl/kenniscentrum/5520/transitienota

The sixth Flemish manure action programme (MAP6) in execution of the EU Nitrates Directive, that will run from 2019 up to 2022, includes an annex with an action plan for manure processing and anaerobic co-digestion. In this annex, the measures to put the VCM vision note into practice during the course of the 6th Flemish manure action programme (MAP6) are outlined. As a first measure, VITO published in 2020 an addendum to the Flemish BAT-document for manure processing (Lemmens *et al.*, 2007; Derden & Dijkmans, 2020), depicting technologies for nutrient recovery as 'emerging technologies' requiring accompanying policy to break through as Best Available Techniques (BAT) in practice. Secondly, an action plan, based on the VCM vision note, to endorse a transition in manure processing to a circular economy, in which various milestones, fixed action periods and interim evaluation will be set, will be developed by the Nutricycle Vlaanderen platform. Therefore, in July 2020, the VCM Workgroup 'Transition in manure processing' was incorporated in the Nutricycle Vlaanderen Workgroup 'Nutrient recovery from manure', presided by VCM, in order to develop this action plan. VCM is also member of the steering committee of Nutricycle Vlaanderen[2].

3.2 RENURE

The objective of the Nitrates Directive (91/676/EEC) is to protect surface and ground water quality from agricultural nitrogen losses. According to article 2(g)[3] of the EU Nitrates Directive, all manure, even in processed form, has to be considered as animal manure and needs to be used under the limit of 170 kg N/ha/year in Nitrate Vulnerable Zones such as Flanders.

The definition of 'livestock manure' hinders the transition towards a circular manure processing:

1. As currently interpreted, the 'animal manure status' results in a **discriminatory (lower) application limit** for all recycled nutrient products recovered from manure, as compared to application limits for virgin mineral fertilisers. This obstacle would oblige transport of the recycled biobased fertilisers over significant distances, although it concerns liquid products with a high nitrogen efficiency.
2. The **value of the end product** has a significant impact on the economic feasibility of these techniques, which are more expensive than current manure processing technologies such as nitrification-denitrification (Gorissen, A. & Snauwaert, 2019). If nutrient recovery techniques produce products with no or even a negative financial value in regions with a high nutrient pressure, these techniques can never have a chance to roll out in practice.

This is confirmed in the addendum to the Flemish BAT-document for manure processing (Derden & Dijkmans, 2020). Technologies for recovery of nitrogen fertilizers from manure such as stripping-

[2] https://nutricycle.vlaanderen/

[3] 91/676/EEC Article 2(g): 'livestock manure': means waste products excreted by livestock: or a mixture of litter and waste products excreted by livestock, even in processed form;

scrubbing and technologies for concentration of nutrients (i.e. membrane filtration) are categorized as '*emerging technologies*' – their TRL (technology readiness level) is too low to be a Best Available Technique (BAT) as the technologies are not applied widely on full-scale in Flanders. The addendum mentions mainly the lack of the end-of-manure statute (implying a low market readiness level) of the products of these technologies next to the higher costs compared to conventional technologies as reason why these technologies are not adopted by the 'early majority' yet.

Action is needed to ensure that the on-going technological and market developments for the recycling of nutrients in a circular economy can be reconciled with the objective of protecting water bodies against pollution originating from livestock manure (Huygens *et al.*, 2020). The recently published 'SAFEMANURE-report' on a study performed by the Joint Research Centre, defines harmonised criteria that could allow nitrogen (N) fertilisers, partially or entirely derived from manure through processing, to be used in areas subject to the ceiling of 170 kg N/ha/yr prescribed in Annex III of the Nitrates Directive (91/676/EEC), following otherwise identical provisions applied to nitrogen containing chemical fertilisers in that Directive, while ensuring the achievement of the Directive's objectives and adequate agronomic benefits. Huygens et al. (2020) thus propose criteria that define the point at which N-rich manure-derived materials meet standards to act as 'chemical fertilisers' as defined in the Nitrates Directive. Such materials are referred to as 'REcovered Nitrogen from manURE (RENURE), as depicted in Figure 1.

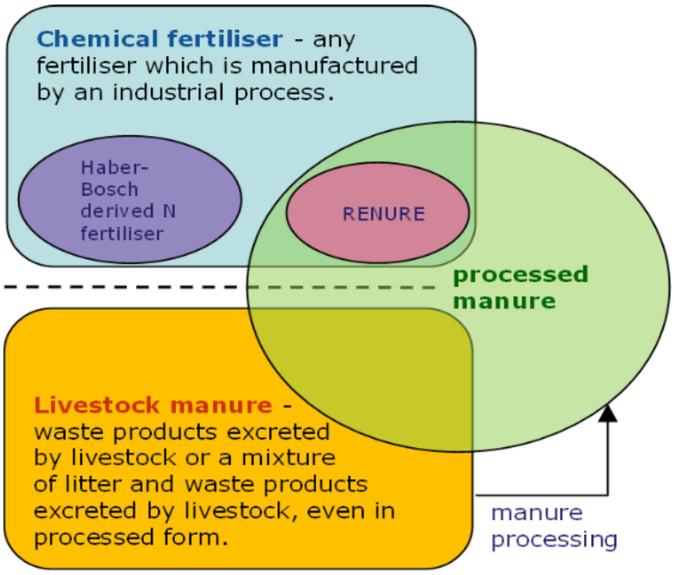

Figure 1 The relation of RENURE to processed manure and livestock manure. Figure from Powerpoint presentation of Wim Debeuckelaere (European Commission, DG ENVI).

3.3 Pioneers in Flanders

In August 2019, VCM launched a call to manure processers, constructors, initiators,… willing to or producing RENURE from manure or digestate. Based on this call, three types of products complying with the RENURE-criteria that are produced in Flanders were selected:

1. **Ammonium salts**, such as ammonium sulphate[4] and ammonium nitrate from stripping-scrubbing;
2. **Mineral concentrates** from membrane filtration processes such as reverse osmosis;
3. **Liquid fraction of digestate** after thorough separation and enhanced solid removal.

As part of the realization of a circular and sustainable manure processing, and awaiting the translation of the SAFEMANURE findings into a European and Flemish policy framework, VCM would like to inform the European Commission on these RENURE-products being produced in Flanders, as well as the currently available information on the technologies producing these products, the characteristics of these products, the environmental impact of the application of these products and the currently relevant Flemish/European legislation.

The Flemish government is taking steps for rapid implementation of the policy framework on the application of RENURE-products as replacement for chemical fertilisers, as soon as it is clearly defined by the European Commission. At least 18 Flemish pioneers (livestock farmers and constructors) are awaiting this policy framework to apply these products, complying to the RENURE-criteria, as a replacement for chemical fertilisers (Table 1).

[4] Here ammonium sulphate, recovered from manure/digestate using a stripping-scrubbing technology is considered. Ammonium Sulphate from air scrubbers is already recognized as chemical fertilizer in Flanders.

Table 1 List of pioneers in Flanders producing or willing to produce RENURE. AS: Ammonium Sulphate, AN: Ammonium Nitrate, MC: Mineral Concentrate and LFD: Liquid Fraction Digestate.

Company	Product	Phase	Application of RENURE (expected) in
1.	AS/AN	Planning/development	2022/2023
2.	AS/AN	Operational (PILOT)	2021
3.	AS/AN	Permit being requested	2022/2023
4.	AS/AN	Permit received	2022/2023
5.	AS/AN	Permit received	2022/2023
6.	AS/AN	Planning/development	2022/2023
7.	AS/AN	Permit being requested	2022/2023
8.	AS/AN	Permit being requested	2022/2023
9.	AS/AN	Planning/development	2022/2023
10.	AS/AN	Planning/development	2022/2023
11.	AS/AN	Planning/development	2022/2023
12.	MC	Operational (FULL SCALE)	2021
13.	MC	Planning/development	2022/2023
14.	MC	Operational (FULL SCALE)	2021
15.	MC	Operational (PILOT)	2021
16.	MC	Operational (FULL SCALE)	2021
17.	LFD	Operational (FULL SCALE)	2021
18.	LFD	Operational (FULL SCALE)	2021

These pioneers are awaiting an end-of-manure statute to invest in a full-scale installation, or only produce small amounts in the context of research projects. Some of them have alternative routes to apply their product (mixing with the dried thick fraction for export, utilization in industrial processes) or apply these products below 170 kgN/ha/year, which is not economically sustainable.

This list of pioneers is constantly growing, as more and more operators are considering investing in nutrient recovery technologies. A clear policy framework could further stimulate innovation and a sustainable implementation as, once RENURE can be applied as replacement for chemical fertilizers, the 'early majority' will become persuaded to invest in new technologies (stripping-scrubbing/membrane filtration) on their plant, and/or to adapt their current operation practices (such as separation technologies) to produce products complying to the RENURE criteria.

3.4 European pilot projects on application of RENURE

In her policy note, the Flemish Minister of Environment, also states she supports, together with the Flemish Minister of Economy, Innovation and Agriculture, further technological research, development and upscaling of best available technologies for nutrient recovery and valorization from manure.

The criteria for safe use of RENURE as replacement for mineral fertilizers are well known and investigated (see 3.2). Further research should focus on the sustainable implementation of the policy framework developed by the European Commission on the application of RENURE. Therefore, in

Flanders, VCM is currently searching funding, together with representatives of knowledge centres and coordination centres from from regions with a high nutrient pressure such as The Netherlands, Spain (Catalonia), Italy (Lombardy), France (Brittany), Malta and members of the Baltic Sea Region, for pilot projects to facilitate the sustainable implementation of the policy framework into practice. During such project, special attention will also be paid to the opportunities to efficiently use the other streams resulting from nitrogen recovery (organic solid fraction, a nitrogen-poor effluent, permeate of filtration processes,…).

These pilots can collect information to help the member state governments develop measurements to reinforce the sustainable application of RENURE based on good agricultural management practices, within their territory. The questions listed in Table 2 will be answered by means of the pilots and by distilling information already available from finished and currently running (European) projects.

Field trials, in which the RENURE can be applied following identical provisions applied to nitrogen containing chemical fertilisers in the Nitrate Directive can be performed 1) as soon as a policy framework is endorsed in Europe and the relevant Member States, and/or 2) based on regional deviations in the context of experimental research of the ceiling of 170 kg N/ha/yr prescribed in the Nitrates Directive and/or 3) with products which can regionally already be used as replacement for chemical fertilisers, (e.g. ammonium sulphate from air scrubbers in Flanders).

In order to support farmers in establishing a more sustainable manure management, all results from the pilots will be disseminated (by means of technical reports, brochures, digital tools, webinars,…) to European farmers. VCM vzw will activate his own unique and international network in the manure processing sector, as well as the network of the Nutricycle Vlaanderen platform (nutricycle.vlaanderen) and the ManuREsource international conference on manure management (www.manuresource.org), and host seminars and workshops to reach all relevant stakeholders and policy makers.

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Table 2 Overview of information that could be gathered in pilots and/or distilled from other finished/currently running (European) projects. NIR: Near Infra Red and NMR: Nuclear Magnetic Resonance.

Question	How will this question be addressed	Possible research initiatives
1. Can technologies for nutrient recovery produce RENURE with a constant, uniform quality and how can the stability of the products be monitored and enforced?	• Research on the appropriate analysis techniques per RENURE product. • Based on an intensive monitoring scheme, stability of the products and the possibility to provide consistent information on the nutrient content will be investigated. • The possibility of certification of the products will be investigated • Effectiveness of measurements with NIR/NMR sensors and necessary calibrations on RENURE can be investigated.	• Literature study • Developing universal analysis methods for RENURE • Follow-up of pilot and first full-scale installations for nutrient recovery by independent research centers. • Desk study and interviews with stakeholders to investigate possibilities for certification of the products.
2. What are the best methods for storage and application of RENURE while ensuring constant stability and preventing ammonia-emissions?	Different storage methods (covers, acidification) and application methods (injection, acidification,…) will be demonstrated and evaluated.	• Literature study • Follow-up of pilot and first full-scale installations for nutrient recovery and conventional installations • Experience-based feedback from technology providers, engineering companies, product providers and farmers • Field trials
3. How can nutrient losses be prevented, what are possible measures and how are these enforced?	Different measures such as catch- and cover crops will be evaluated on their efficiency.	• Literature study • Field trials
4. How can the trade and logistics of RENURE be organized?	• A simulation on the effect of trade in RENURE on Flemish manure management will be executed. • The possibility of central distribution of RENURE will be investigated. • The possible prices of RENURE will be evaluated. • Logistics will be compared with present logistics of products already applied as replacement for chemical fertilizers (scrubber water air scrubbers).	• Desk study (modelling) • Interviews with stakeholders • Literature study
5. What are the factors that make a business producing RENURE-products successful or a failure?	Business cases of the innovators will be evaluated, and strengths, weaknesses, and key performance indicators will be identified	• Desk study (cost-benefit analysis) • Interviews with stakeholders • Literature study
6. How can RENURE be applied in nutrient management practices and fertilization strategies in conventional and organic farming to increase the nutrient use efficiency, complying with the Farm to Fork Strategy?	• Renowned knowledge centers will propose and test possible nutrient management practices and fertilization schemes, strengthened by analysis of the products and fertilization advices for individual parcels where RENURE will be applied. • Special attention is also paid to the efficient use of other streams resulting from nitrogen recovery (organic solid fraction, N-poor effluent and permeate of filtration processes). • RENURE will be compared to fertilisers allowed in organic farming	• Desk study • Literature review • Field trials
7. What is the environmental impact of RENURE production and application compared to conventional mineral fertilizers?	LCA-studies will be performed on the technologies producing RENURE (including the storage and application of the products), comparing them with conventional manure processing technologies and the production/application of chemical fertilizers. Special attention is going to the impact on water quality (cfr. objectives Nitrates Directive).	• LCA study/modelling • Laboratory studies • Field trials
8. What are the policy related barriers still remaining?	Remaining practical, technical, and legislative bottlenecks will be identified	Policy workshops leading to policy recommendations, including bottlenecks and suggestions from different stakeholders.
9. How will the new technologies and the application of RENURE will be rolled out in Europe?	• Based on diffusion of Innovation Theory, the Adoption Curve for application of nutrient recovery technologies and application of RENURE is designed and analyzed for the different regions. • Per region, a customized market strategy to persuade the next group of adopters is developed.	• Desk study • Interviews with stakeholders • Development of market strategy

4 Current state of manure processing in Flanders

Every year, the Flemish Coordination Centre for Manure Processing organizes an inquiry about the situation and evolution of the manure processing in Flanders. All data on 2019 can be found in the Dutch report (VCM vzw, 2020).

The results for 2019 show that 49,8 million kg nitrogen from animal manure was processed and/or exported, corresponding to 5,1 million tonnes of animal manure processed in Flanders. The evolution of manure processing (in tonnes) is given in Figure 2.

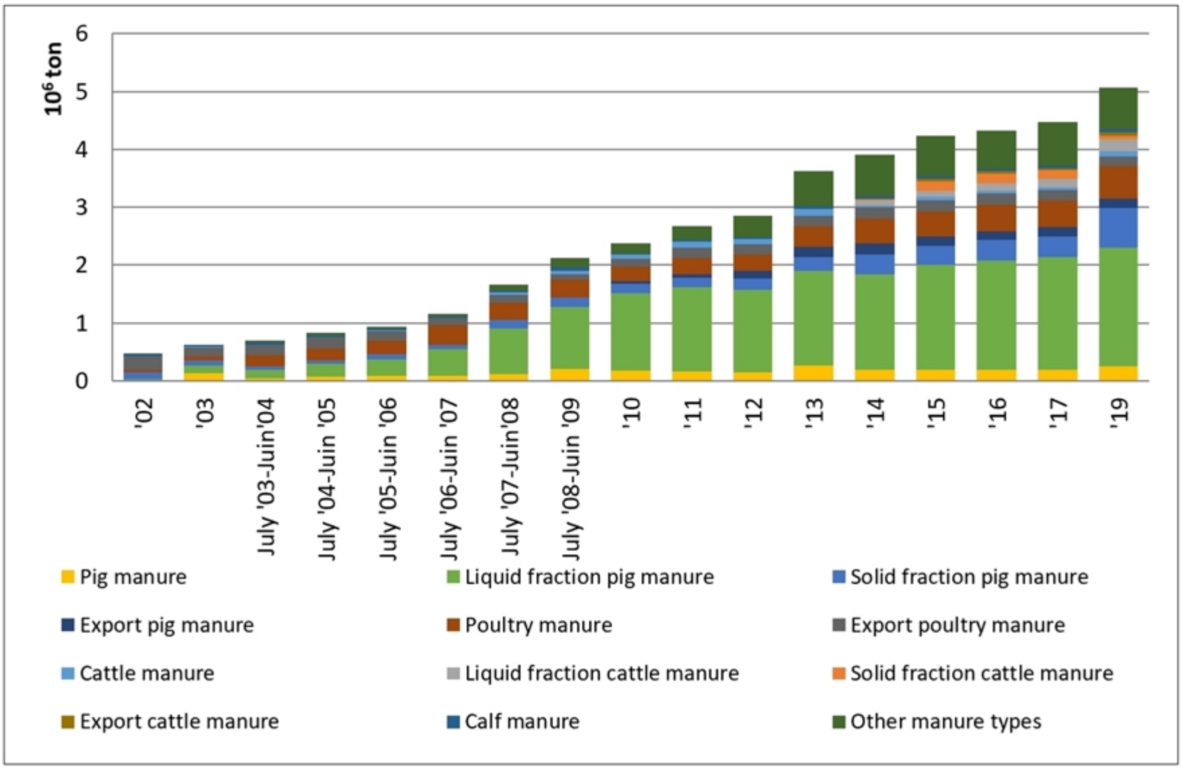

Figure 2 Evolution of manure processing in Flanders. Treatment in different fractions of manure (in tonnes).

The largest part (almost 87 %) of the treated amount of nitrogen in 2019 was realized by the treatment and export of Flemish pig manure (in total 21,2 million kg N or 42,6 %) together with the treatment and export of poultry manure (in total 22,2 million kg N or 44.6 %).

The most applied technology (104 of the 136 installations) in Flanders is the biological treatment (nitrification-denitrification) from the thin fraction of pig manure, cattle manure and/or digestate, followed by the biothermical drying (17 installations) of the thick fraction.

In 2019, the largest part of treated nitrogen was treated by means of biothermical drying (of poultry manure, horse manure and the thick fraction of pig and cattle manure), sometimes followed by further drying and granulation (18.4 million kg N or 42.3%). A smaller amount of nitrogen (12.9 million kg N or 29.8 %) was treated by means of the biological treatment (of pig and cattle manure and digestate), sometimes followed by further treatment of the potassium rich effluent by means of constructed wetlands. The largest amount of phosphate (15 million kg P_2O_5) or 55.6 % is treated by means of biothermical drying (sometimes followed by drying and granulation).

It can be concluded that the conventional technique of manure treatment in Flanders, i.e. the separation of the raw manure in a thin fraction, which is treated biologically by means of nitrification-denitrification and a thick fraction, biothermically dried in a composting process and exported afterwards (mainly to France), is currently crucial for an efficient treatment of the Flemish manure surplus.

5 Relevant legislation

5.1 Relevant Flemish legislation

5.1.1 *Manure Decree*

The judicious application of fertilizers in Flanders is ensured by means of the overall Flemish manure policy as described in the Flemish manure decree and enforced by the relevant administration, which is the VLM Mestbank. This involves specific measures related to the sixth manure action program (MAP6) such as the obligation of sowing catch crops in certain circumstances, monitoring of the post-harvest nitrate residues and emission-low application.

The application of the RENURE-products listed in this document, is above all subject to this Flemish manure legislation, with the 4 R's being central:

1. **Right manure type**: the biobased fertilisers in this document are high quality nitrogen fertilisers with a *high Nitrogen Fertiliser Replacement Value* (NFRV). The NFRV coefficient reflects the amount of N-fertilizer that can be replaced by manure-N; the higher the availability of the nitrogen from the applied product to the crop in the season during which the product is applied, the higher the nitrogen efficiency of the product and the higher the NFRV (Heinen *et al.*, 2020; Schils *et al.*, 2020).

2. **Right dose:** The application of RENURE is bound to the maximum nitrogen (and phosphorus) limits defined in Flemish manure legislation. The nitrogen limits depend both on the specific area in which the product will be applied, the soil type and the crop. Specific fertilisation maxima are defined by the VLM Mestbank; however, it is advised to base the application of all the products on fertilisation recommendations.

3. **Right moment**: The application time of the biobased products is bound to the legal application period defined in Flemish manure legislation, but the farmers can be advised on the best time to apply the products, for example by means of fertilisation recommendations.

4. **Right technology for application**: to reduce ammonia emissions, emission-free technologies (injection, trial hose, fast incorporation of manure after spreading) are already obliged for specific types of liquid animal manure and could also be obliged for specific RENURE prone to ammonia emissions during spreading.

The abovementioned 4 R's are reflected in the good agronomic practice in Flanders, for example promoted in different practical guides for sustainable fertilization (Departement Landbouw & Visserij, 2014, 2015; Vanrespaille *et al.*, 2018). Following these good agronomic practices, RENURE will be applied based on analyses and adequate fertilisation recommendations, a service offered by the official recognized labs performing manure analyses.

From 2021, Flemish farmers and traders in mineral fertilizers will need to keep track of the traded/used mineral fertilisers using a digital mineral fertiliser register. As soon as RENURE will be able to be used as replacement for chemical fertilisers, these products will also be tracked based on these digital registers.

5.1.2 *VLAREMA*

VLAREMA is the Flemish legislation dealing with the ‘end-of-waste’-statute of biological treated organic biological waste streams. All products originating from digestate from an anaerobic digestion installation treating both manure and organic biological waste streams (co-digester), are subject to this legislation. VLAREMA points out that input streams for the biological treatment processes as well as the end products (being used as fertiliser or soil improver) must comply to strict criteria concerning composition, dosing, etc. for heavy metals and organic pollution. Furthermore, VLAREMA obliges certification for the installations, handed out by VLACO.

All RENURE-products coming from digestate from an installation treating also organic waste streams, need to comply to the VLAREMA criteria (Annex 2.3.1A/B and 2.3.1.C) and they need a certificate from VLACO.

5.1.3 *Trade in the biobased fertilisers and registration as fertiliser trader*

Trading of end products of manure processing is regulated at federal level through the Royal Decree of 28 January 2013. If end products of fermentation (digestate) and manure processing are not listed in Annex I of this legislation, an exemption for these products from the Public Health Department; Food and Environmental Safety section (FAVV) is needed. This FOD-exemption is valid for a maximum of 5 years.

To trade in fertilisers/soil improvers that are no ‘natural products from the farm’, companies must have formal FAVV-approval. Annual inspection visits are carried out by FAVV inspectors. Checklist are audited (reporting duties, traceability, infrastructure, equipment, hygiene, packaging, and labelling and auto- checks).

5.2 Relevant European legislation

5.2.1 *Nitrates Directive and SAFEMANURE study*

In September 2020 a final report was published by the Joint Research Centre (JRC) on SAFEMANURE, a study conducted by JRC commissioned by DG ENVI (Huygens *et al.*, 2020). The report proposes criteria for the safe use of RENURE in Nitrates Vulnerable Zones above the threshold established by the Nitrates Directive (170 kg N/ha/year). A new term for Recovered Nitrogen from Manure, RENURE, was introduced. All products mentioned in this document are able to comply to the following criteria:

- RENURE materials should have a mineral N:total N ratio ≥ 90% or a total organic carbon (TOC):total N ratio ≤ 3, where the ratios should be adjusted for any Haber-Bosch-derived N added during the manufacturing process.
- RENURE materials should not exceed the following limit values:
  - Cu: 300 mg kg^{-1} dry matter;
  - Zn: 800 mg kg^{-1} dry matter.
- Member States should take the necessary provisions so that the timing and application rates of RENURE are synchronised with plant nutrient requirements to minimise nutrient leaching and run-off losses involving in particular specification of information on the nutrient content of the RENURE and maintaining a living plant cover on the land for as much of the year as possible or equivalent measures.
- Member States should take the necessary provisions to prevent and minimise NH_3 emissions during RENURE application on the field, especially
  - for RENURE N fertilisers that have > 60% of its total N present in a form other than NO_3^-- N; and
  - for RENURE N fertilisers applied on soils of pH_{H2O} > 5,5.
- Member States should take the necessary provisions to prevent and minimise emissions to air resulting from storage through enforcing appropriate storage conditions of RENURE.

5.2.2 *Fertilising Product Regulation*

On 5 June 2019, the Fertilising Products Regulation (FPR) was adopted as first deliverable of the Circular Economy Action Plan. This new Legislative Framework replaces the existing Fertilisers Regulation 2003/2003 and comprises harmonised rules for mineral and organic fertilising products. Fertilisers with a CE-marking can move freely in the European market.

The FPR is a product regulation and does not regulate the use of products or mode of application. Furthermore, as the products in this document are high value liquid nitrogen fertilisers, they are produced mainly for local application in Flanders. Therefore, the FPR is probaly less relevant for the RENURE-products.

The criteria in the SAFEMANURE study for heavy metal content are based on the criteria of CMC (Component Material Category) 10 (derived products from animal by-products). The list for CMC 10 is still to be updated, and possibly products complying with the RENURE-criteria will be listed as CMC 10.

5.2.3 *Regulation (EC) No 1069/2009 and No 142/2011*

The Flemish RENURE-products will be applied most probably locally in Flanders, close to the production site. Hygienisation will therefore not be necessary as Article 13 of Regulation (EC) No 1069/2009 indicates that manure ‘can be applied to land without processing’ if the competent authority does not consider it a risk for the spreading of serious transmissible diseases. As the RENURE in this document will not be placed on the market but be applied locally on land, there is no need to apply any form of hygienization.

6 Relevant (European) projects and pilots

Besides the before mentioned SAFEMANURE study, conducted by JRC commissioned by DG ENVI, other projects on this topic summarize nutrient recovery technologies, the characteristics of their products and the application of these biobased fertilisers in field trials. Even now, different projects on these topics are being executed. VCM or members of VCM are/were involved as partner or as part of the advisory group in several projects investigating nutrient recovery technologies for digestate and/or manure and their end-products.

Most of these projects, and relevant publications resulting from these projects, are listed below in Table 3 (finished projects) and Table 4 and Table 5 (running projects). Relevant information from these projects was used to complete the product Chapters (Chapter 7-9).

Table 3 Finished projects which collected relevant information for production/application of RENURE. AS: Ammonium Sulphate, AN: Ammonium Nitrate, MC: Mineral Concentrate and LFD: Liquid Fraction Digestate.

Project Name	Program	Status	Topic	RENURE tested	Conclusions
WINGS	Danone Ecosysteme Fund	Finished (2016-2019)	Demonstration of innovative manure processing technology for nitrogen recovery from dairy manure	AN	• A brochure was published on technologies for treatment of cattle manure (Gorissen, A. & Snauwaert, 2019) • It was concluded that stripping-scrubbing is technically, but not economically, feasible as long as the products do not have an end-of-manure statute. • Field trials with fodder grass in 2019 showed comparable yields between (AN) and convential CAS, even after a dry, hot summer. Attention should be paid to the nitrate residue, which was higher for the ammonium nitrate plot, and the application methods (in this case the N-concentration was rather low, implying a very slow application speed of the sprayer).
BIOREFINE	Interreg NWE	Finished (2011-2015)	This project addressed the recycling of inorganic chemicals from agro- and bio industrial waste streams.	Amongst others AS and LFD	• A Dutch brochure on field trials with biobased fertilisers was published (De Clercq *et al.*, 2015). • In a field trial with energy maize, the use of AS and LFD as replacement of animal manure and conventional chemical fertilizers, was shown to result in a same yield, physico-chemical soil fertility and quality. • No significant difference was found between dry and fresh weight of lettuce fertilized with biobased fertilizers such as LFD and AS together with chemical fertilizers, compared to the reference trial fertilized with mineral fertilizers only. Similar conclusions were drawn for cauliflower trials. • It was concluded that AS is a valuable replacement for chemical fertilizers. It adds also sulfur to the soil. Caution is needed to prevent a surplus of sulphur in the soil. • LFD can result in improvements in yield and soil quality. However, nitrogen efficiency can be difficult to predict in digestate due to the varying composition. • A platform for collaboration between projects, the Biorefine cluster (www.biorefine.eu) was started up in the margin of the Biorefine project.
ARBOR	Interreg IVB North West Europe	Finished (2010-2014)	ARBOR's mission was to foster and accelerate sustainable development and use of biomass in North West Europe.	Amongst others AS and LFD	• An inventory on the technologies for nutrient recovery and their end products was published (Lebuf et al., 2013). • Also a case study report with an overview of legislation, technologies, economical and environmental assessment of the techniques for nutrient recovery from digestate, with some results of field tests, was published (Lebuf, V., Michels, 2015). • Further research was necessary to assess the long-term effects of use of biobased fertilisers and attention should be given to the 'form' and nutrient concentration of the products as this can affect their applicability. • A report on P-recovery showed that a Fraunhofer IGB technology was technicially and possibly economically feasible in Flanders. However, a pilot in Flanders is necessary to further investigate economical feasibility and possible business plans (VCM vzw, 2015).
Nutricycle	MIP-ICON	Finished (2011-2014)	This project focused on the recovery of nutrients from manure and digestate and their reuse as green fertilizer substitutes.	-	• Amongst other initiatives (visits of innovative installations, workshops,…), a brochure on export of products from manure processing to France (Van Elsacker & Snauwaert, 2016) was published.
DIGESMART	CIP-EIP-Eco-Innovation	Finished (2013-2016)	In DIGESMART all stakeholders were brought together for the installation of a new process to minimize spreading digestate flows and to economically valorize the minerals (nitrogen, phosphorus and potassium, among others).	AN	• A brochure (Biogas-e, 2016a) gives more information on the investigated technology (stripping-scrubbing) • Another brochure (Biogas-e, 2016b) summarizes the field test results. Trials in lettuce, maize and wheat conducted in Flanders and Italy showed that AN has the same performance of conventional liquid fertilisers. It was noticed that attaining stable product concentrations is a work in progress. Also, the liquid formulation sets a limit on the adaptation in agriculture as most farming practices are based on granulated chemical fertiliser products. • Also a LCA study on the stripping-scrubbing of liquid fraction of digestate was published (Biogas-e, 2016c). It was concluded that the environmental results of the different solutions for digestate management deeply depend on the assumptions and the considered system boundary. Future studies need to consider the nitrogen efficiency of the fertilizers (i.e. 100% for RENURE), impact of increased transport of liquid fertilizers, a system boundary expansion including storage of raw digestate as well as the different fractions before being spread.

Table 4 Current projects collecting information on technologies and application practices of RENURE.

Project Name	Program	Status	Topic	RENURE tested	Conclusions
SYSTEMIC	Horizon 2020	Running (2017-2021)	The SYSTEMIC project works to facilitate the transition to a circular economy in Europe by demonstrating new approaches to nutrient recovery from biowaste (amongst others animal manure).	AN, AS, MC and LFD	• Fact sheets on AN, AS, MC and liquid fraction digestate were published and were used in the product chapters of this information document (Chapter 7-9).
NITROMAN	Interreg NL-VL	Running (2019-2022)	NITROMAN will test two different innovative techniques to recuperate considerable amounts of nitrogen, potassium and water from the liquid fraction of the manure. The recuperated nitrogen and potassium can subsequently be applied as fertilizer in the agriculture.	AN, AS, MC and LFD	• Pilot installations (stripping-scrubbing and reverse osmosis installations) will be installed at a number of livestock farms located near the Flemish-Dutch border • The products of these installations, e.g. ammonium nitrate, ammonium sulphate and mineral concentrates, will be applied on demonstration field tests.
Nutri2Cycle	Horizon 2020	Running (2018-2022)	Nutri2Cycle will help closing nutrient loops with a genuine approach that will consist of: • Identifying the most efficient types of farm systems in Europe; • Defining indicators to monitor and demonstrate the environmental advantages of more efficient, closed nutrient loops; • Establishing innovative business cases at pilot scale (12-16 pilots)	-	• Create more efficient and sustainable farm business models for nutrient recovery and recycling. • Spread the results at regional, national and European level throughout a comprehensive network of regional operational groups, National Task Forces and European stakeholders. • Assess how the products obtained through the identified business models can aim for labelling and reach end-users. • Provide scientific support on effective regulatory frameworks to reduce emissions and increase self-reliance of Europe for food, energy and nutrients in the next century.
RENU2FARM	Interreg NEW	Running (2017-2020)	The ReNu2Farm project is designed to increase the recycling rates for the plant nutrients nitrogen (N), phosphorus (P) and potassium (K) in the primary food production chain in Northwest Europe (NWE).	AS, AN, LFD	• Desk studies for assessment of the regional demand for nutrients and performances of the products • Assessment of economic market value of the products based on production costs and interest amongst the stakeholders • Field trials in the Netherlands, Ireland, France and Belgium. • Inagro (Belgium, maize) researched the nitrogen value at short-term of revered liquid nitrogen products (LDF, AN and AS). This trial was part of the SAFEMANURE study.

Table 5 Current projects collecting information on technologies and application practices of RENURE (continued).

Project Name	Program	Status	Topic	RENURE tested	• Conclusions
NUTRIMAN	Horizon 2020	Running (2018-2020)	The objective of NUTRIMAN is to improve the exploitation of these commercially and market ready-for-practice cases of N/P nutrient management/recovery potential that are not yet sufficiently known by practitioners.	-	• Farmer Platform (overview of products and technologies for nutrient recovery) at www.nutriman.net • Survey for farmers on the use of products from nutrient recovery
UNIR	Vlaanderen Circulair	Running (2019-2020)	This project aims to close the local agricultural nutrient loops, by replacing mineral fertilizers by means of the scrubbing water from chemical air washers.	AS	• Centralization and standardization of AS • Filter system for removal of impurities • Optimized row fertilization using a trial hose system • Field trials (Grass, Maize) in 2019 indicated a comparable yield compared to fertilization with CAS, a dark green color of the grass, no burning of the crop and equal or even lower nitrate residues.
Fertimanure	Horizon 2020	2020-2023	The EU-funded FERTIMANURE project intends to develop, test and estimate advanced nutrient management strategies to produce competitive fertilisers.	MC, AS, AN,…	The technological side will be addressed with the implementation of 5 innovative & integrated on-farm experimental pilots for nutrient recovery in the most relevant European countries in terms of livestock production (Spain, France, Germany, Belgium, The Netherlands), whereas nutrient management will be addressed through 3 different strategies adapted to mixed and specialized farming systems: • Strategy #1 with on-farm production and use of bio-based fertilisers; • Strategy #2 with on-farm Biobased fertiliser production and centralised tailor-made fertilisers; • Strategy #3 with on-farm Tailered made fertiliser production and use.

7 PRODUCT CATEGORY 1: scrubbing salts

The information in this chapter is based on Brienza et al. (2020) and Sigurnjak (2020) and fact sheets made up in the margin of the SYSTEMIC project. More elaborate information can be found in the accompanying SYSTEMIC brochure (Ehlert *et al.*, 2019).

7.1 Ammonium sulphate

7.1.1 *Technology description*

Ammonium (NH_4^+) and ammonia (NH_3) are both the same basic compound, yet the first is water soluble form whereas the second is the volatile gaseous form. Both these forms are in dynamic equilibrium in which increasing pH and/or temperature will convert more water soluble ammonium into the gaseous ammonia. In manure or digestate treatment systems this basic chemical principle can be used to extract ammonium nitrogen from manure via a system that is called 'stripping' (which converts it into volatile ammonia via pH and/or temperature increase) followed by 'scrubbing' to recapture the extracted ammonia back into soluble ammonium through a low pH 'scrubber' solution (Figure 3). Ammonium sulphate can thus be obtained by removing ammonia (NH_3) from nitrogen (N-) rich air or from N-rich biomass streams.

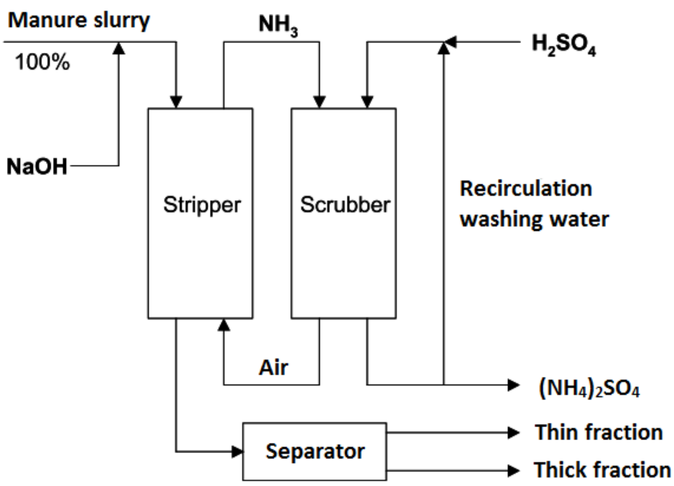

Figure 3: Schematic overview of the stripping and scrubbing technique to recover ammonia from manure (Melse et al., 2004).

7.1.2 *Product characteristics*

Similar to synthetic produced mineral N fertilisers, ammonium sulphate contains total N entirely in mineral form, as NH_4-N. Since the product is obtained by means of sulphuric acid, ammonium sulphate is also an important source of sulphur (S). Depending on the amount of added acid, it is not only S concentration that will vary, but also the pH and Electrical Conductivity (EC). Low pH and high EC values should be taken into account during the product application process since it can cause the corrosion of machinery, reduction of the soil pH and burning of leaves if applied on the crop.

The average characteristics of ammonium sulphate are summarized in Table 6. Average figures for ammonium sulphate from air cleaning installations are given, as there are air scrubbers active on Flemish manure digestate/manure drying facilities. Until now, there are no installations producing ammonium sulphate directly from manure or digestate active yet in Flanders.

Table 6 Product characteristics of ammonium sulphate (from air cleaning) in ranges based on average values reported in scientific studies. EC: electrical conductivity.

Parameter	Ammonium sulphate
Dry matter (%)	14 - 33
pH	2.40 - 6.43
EC (mS cm^{-1})	157 - 262
N total (g kg^{-1})	30 - 86
NH_4-N (g kg^{-1})	30 - 86
N mineral/N total (%)	100
S (g kg^{-1})	30 - 114

7.1.3 *Agronomic aspects*

Plants (and by extension crops) require nitrogen in mineral form in order to take it up. For example, a common synthetic nitrogen fertiliser of which full plant availability is assumed, is CAN (Calcium ammonium nitrate). An ammonium sulphate rich solution will enjoy the same characteristics as CAN regarding nitrogen availability to crops. Ammonium sulphate solutions will differ from ammonium nitrate solutions by its lower overall nitrogen concentration and obviously by the fact that also sulphate will be present in the solution. This needs to be considered to avoid adding excessive doses of sulphate beyond the crop’s requirement.

So far, seven individual agronomic trials on ammonium sulphate from air cleaning have been identified and three trials on ammonium sulphate from stripping-scrubbing (Vaneeckhaute *et al.*, 2013, 2014; Chen, 2014; Biogas-e, 2016b; Sigurnjak *et al.*, 2016). Their main focus was to assess the effect of the ammonium sulphate on crop yields and to determine N fertiliser value (Figure 4).

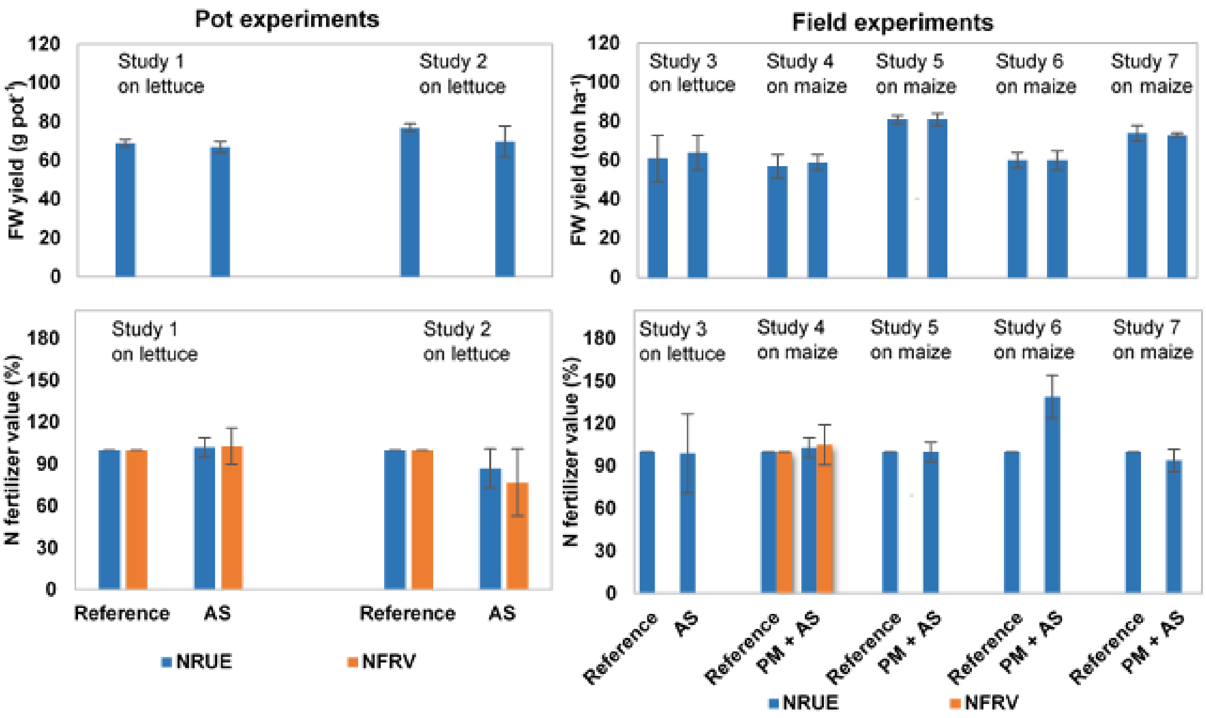

Figure 4: Effect of ammonium sulphate (AS), from air cleaning, on fresh weight (FW) yield and its nitrogen (N) fertiliser value compared to conventional fertilisation regime in lettuce (Reference = calcium ammonium nitrate (CAN; 27% N) as synthetic N) and maize (Reference = pig manure (PM) + CAN). N replacement use efficiency (NRUE) does not account for the effect of unfertilized treatment, whereas N fertiliser replacement value (NFRV) takes into account the effect of unfertilized treatment. To determine NRUE and NFRV of ammonium sulphate, the reference treatment is considered to be 100% effective.

Determination of the N fertiliser values (N Replacement Use Efficiency; NRUE and N Fertiliser Replacement Value; NFRV) depends on the presence or the absence of a control (=unfertilized) treatment in an experimental design, and hence can be determined as follows:

$$NRUE\ (\%)\ =\frac{(N\ uptake\ AMM.SULPHATE\ /\ total\ N\ applied\ AMM.SULPHATE)}{(N\ uptake\ REFERENCE\ /\ total\ N\ applied\ REFERENCE)}*100$$

$$NFRV\ (\%)=\frac{((N\ uptake\ AMM.SULPHATE-N\ uptake\ CONTROL)\ /\ total\ N\ applied\ AMM.SULPHATE)}{((N\ uptake\ REFERENCE-N\ uptake\ CONTROL)\ /\ total\ N\ applied\ REFERENCE)}*100$$

Current results indicate that compared with chemical nitrogen fertilizers such as CAN, there is no positive nor negative effect on crop fresh weight yield if recovered ammonium sulphate is used as a N fertiliser in the cultivation of lettuce and maize, i.e. a similar effectivity is found. In all seven studies on ammonium sulphate from air cleaning similar yields were obtained as in the reference treatment that represented the conventional practice of using only synthetic N or synthetic N in addition to animal manure.

Although the electrical conductivity of ammonium sulphate is high and the pH is low, both parameters did not reduce crop yield. The main reason is that due to the high N concentration in ammonium sulphate

(27 – 86 g kg^{-1}), compared to animal manure (3-5 g N kg^{-1}), only low amounts are applied. Furthermore, the soil also has a buffer capacity to neutralize the potentially low pH of ammonium sulphate. Of course, attention should be taken when applying ammonium sulphate to salt sensitive crops. On the other hand there are crops that can handle high EC values of ammonium sulphate and also benefit from sulphur application (e.g. cabbages).

In six out of seven studies, researchers have reported that NRUE and/or NFRV of ammonium sulphate is similar to the conventional fertilisation regime where synthetic N fertiliser is used as a sole source of N (lettuce cultivation) or on top of pig manure (maize cultivation). Only in study 6 (Figure 4) was a significant positive effect reported on NRUE of the manure plus ammonium sulphate treatment (Pig Manure + Ammonium Sulphate) compared to the reference regime, which was a result of higher N uptake by the crop in PM+AS treatment. In two out of three studies, researchers have reported that NFRV of ammonium sulphate from (stripping)-scrubbing systems is similar to the conventional fertilisation regime where synthetic N fertiliser is used as a sole source of N in pot cultivation of spring wheat (Figure 5). In a pot study with maize, ammonium sulphate from (stripping)-scrubbing system has resulted in lower NFRV than mineral ammonium nitrate that was used as a reference. The studies do not report any information on NRUE.

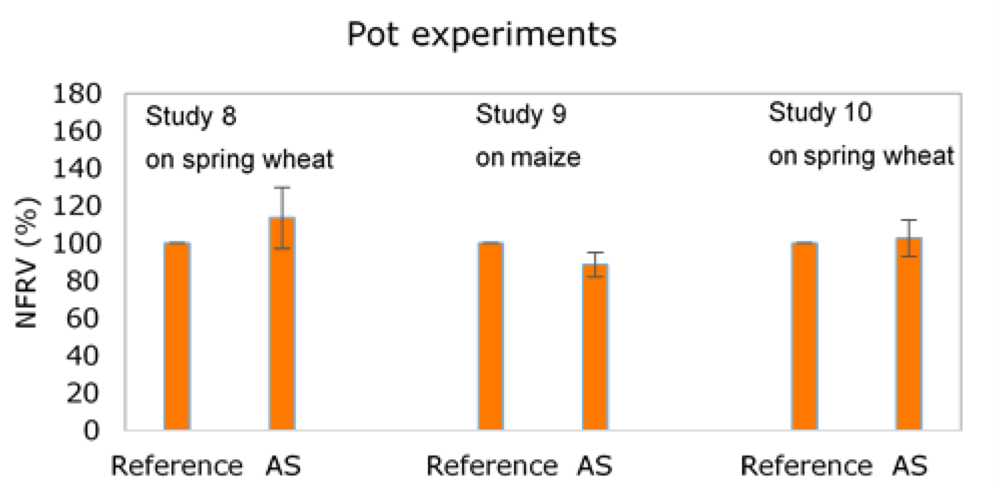

Figure 5: Effect of ammonium sulphate (AS), from (stripping)-scrubbing system, on nitrogen fertiliser replacement value (NFRV; %) compared to conventional fertilisation regime of using ammonium nitrate in pot experiments with spring wheat and maize. To determine NFRV of ammonium sulphate, the reference treatment is considered to be 100% effective.

In general, studies on NRUE and NRFV tend to show a notable variation across different experiments. This variation stems from the effects of variable weather conditions on the performance of both bio-based materials and the used references.

7.1.4 *Environmental aspects*

Environmental aspects have been assessed in the field experiments by measuring post-harvest nitrate residue. The measured nitrate residue gives an estimation of the nitrate amount that can potentially leach to ground and surface water. This procedure has been used in Flanders (Belgium) since MAPII. In studies that measured the postharvest nitrate residue, no significant differences were observed between the reference treatment and the treatment where ammonium sulphate was used as a N source (Figure 6). The measured residues were below the maximum allowable level of 90 kg NO_3-N ha^{-1} in 0-90cm soil layer, with an exception of study 5 where exceedance was observed for the both reference and ammonium sulphate treatment.

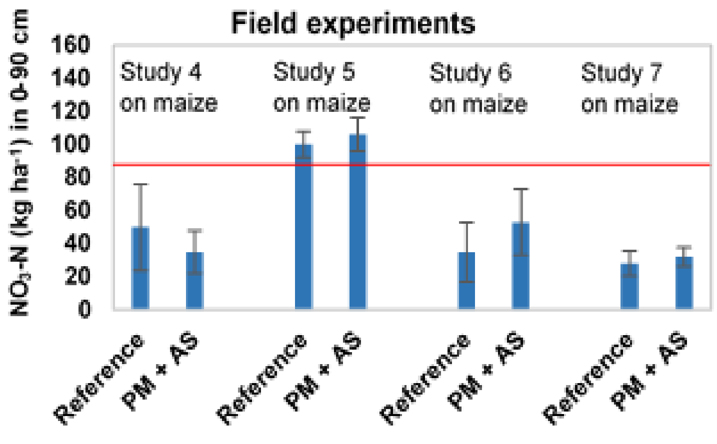

Figure 6: Effect of ammonium sulphate (applied in combination with pig manure) and conventional fertilisation (Reference = pig manure (PM) + CAN) on post-harvest nitrate residue (kg ha-1) in 0-90 cm soil layer. The red line indicates the maximum allowable level

Due to the high mobility of nitrate, the measured nitrate residue is highly influenced by weather conditions. Therefore, the observed exceedance in study 5 was attributed to unfavourable weather conditions – a warm and dry growing season, which has led to the exceedance of maximum allowable nitrate level in 40% of all taken measurements in West Flanders (Belgium).

7.1.5 *Current legal view on ammonium sulphate*

The Nitrates Directive defines this product, if recovered directly from manure/digestate, as animal manure and not as mineral N fertiliser. Therefore, the product has to fulfil the use requirements of animal manure, and therefore has to compete with animal manure (which has no, or a negative, financial value). In Flanders ammonium sulphate from air scrubbers is recognized as chemical fertilizer.

Analyses during the SAFEMANURE study (Huygens *et al.*, 2020) showed that ammonia salts such as ammonium sulphate comply well with the proposed criteria.

In Table 7, the ammonium sulphate produced by a constructor who provided information for this document, is compared to the RENURE-criteria; it can be concluded that this ammonium salt (Category 1) most probably will indeed be able to comply with these criteria. If not, the process circumstances can be adapted to comply with the criteria.

Table 7 Average composition of ammonium sulphate (AS) from a provider who submitted a file for this document.

	kg N_{min}/ton	**kg N_{tot}/ton**	**% DS**	**N_{min}/N_{tot}**	**Cu (mg/kg DM)**	**Zn (mg/kg DM)**
AS	64,0	NA	2,5	>0,9	<5	<20

7.2 Ammonium nitrate

7.2.1 *Technology description*

Ammonium (NH_4^+) and ammonia (NH_3) are both the same basic compound, yet the first constitutes the water soluble form whereas the second is the volatile gaseous form. Both these forms are in dynamic equilibrium; increasing pH and/or temperature will convert more water soluble ammonium into the gaseous ammonia and vice versa. In manure or digestate treatment systems this basic chemical principle can be used to extract ammonium nitrogen from manure via a system that is called ‘stripping’ (which converts it into volatile ammonia via pH and/or temperature increase) followed by ‘scrubbing’ to recapture the extracted ammonia back into soluble ammonium through a low pH ‘scrubber’ solution. If a nitric acid solution is used ammonium nitrate will be formed. During the VCM – Danone WINGS project, a stripping-scrubbing installation producing ammonium nitrate from cattle manure was tested (Figure 7).

Figure 7 Ammonium nitrate solution (left) from the stripping-scrubbing installation (middle & right) during the WINGS project.

7.2.2 *Product characteristics*

Similar to synthetic produced mineral N fertilisers, ammonium nitrate contains total N entirely in mineral form, as NH_4-N and NO_3-N (Table 8). Usually higher N concentrations (2x) are measured in ammonium nitrate as compared to ammonium sulphate. Depending on the amount of added acid the pH and electric conductivity (EC) can vary. Higher pH values can often be observed when compared to ammonium sulphate, which reduces the risk of machinery corrosion, but also results in higher risk of ammonia volatilization.

Table 8 Product characteristics of ammonium nitrate after N–stripping/scrubbing of liquid fraction of digestate from animal origin in ranges based on average values reported in scientific studies. EC: electrical conductivity.

Parameter	Ammonium nitate
Dry matter (%)	48
pH	6.92 - 7.85
EC (mS cm^{-1})	332 - 342
N total (g kg^{-1})	132 - 198
NH_4-N (g kg^{-1})	76 - 109
NO_3-N (g kg^{-1})	56 – 89
N mineral/N total (%)	100

7.2.3 *Agronomic aspects*

Plants (and by extension crops) take up nitrogen in a mineral form. For example, a common synthetic nitrogen fertiliser of which full plant availability is assumed is CAN (Calcium Ammonium Nitrate). In essence, an ammonium nitrate rich solution will present the same crop availability than CAN.

Up to now, results from three individual published agronomical trials with ammonium nitrate have been identified (Biogas-e, 2016b; Sigurnjak *et al.*, 2019). Their main focus was to assess the effect of the ammonium nitrate on crop yield and to determine its N fertiliser value (Figure 8).

Determination of the N fertiliser values (N Replacement Use Efficiency; NRUE and N Fertiliser Replacement Value; NFRV) depends on the presence or the absence of a control (=unfertilized) treatment in an experimental design, and hence can be determined as follows:

$$NRUE\ (\%) = \frac{(N\ uptake\ AMM.NITRATE\ /\ total\ N\ applied\ AMM.NITRATE)}{(N\ uptake\ REFERENCE\ /\ total\ N\ applied\ REFERENCE)} * 100$$

$$NFRV\ (\%) = \frac{((N\ uptake\ AMM.NITRATE - N\ uptake\ CONTROL)\ /\ total\ N\ applied\ AMM.NITRATE)}{((N\ uptake\ REFERENCE - N\ uptake\ CONTROL)\ /\ total\ N\ applied\ REFERENCE)} * 100$$

The identified studies reported slightly higher crop yields when ammonium nitrate was applied as a N source in lettuce cultivation. In maize cultivation, no significant differences were observed on crop fresh weight yield when ammonium nitrate was used as a N fertiliser compared to the conventional fertilisation regime (=reference).

Because of higher lettuce yield in pot experiments, treatments with ammonium nitrate also resulted in higher NRUE/NFRV values as compared to conventional fertilisation regime where synthetic N fertiliser is used as a sole source of N. In maize cultivation, no differences were observed regarding NRUE or NFRV when ammonium nitrate was used as a N fertiliser compared to the conventional fertilisation regime of using synthetic N on top of animal manure. This means that ammonium nitrate exhibits a similar effect on crop yield as synthetic N fertiliser, and as such can be used as a valuable N source and as a replacement for synthetic fertilisers.

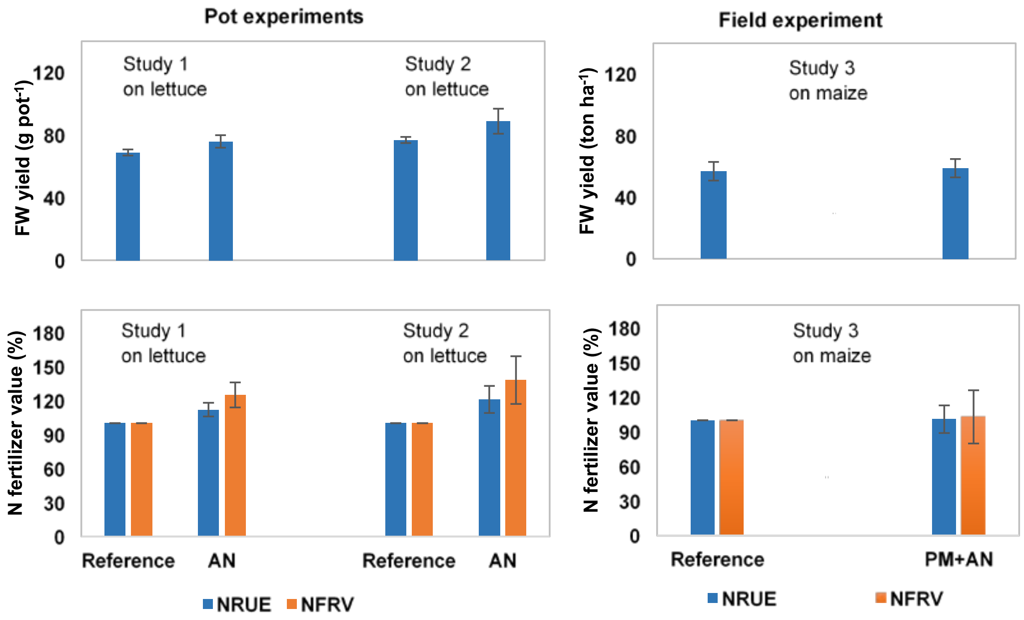

Figure 8: Effect of ammonium nitrate (AN) on fresh weight (FW) yield and its nitrogen (N) fertiliser value compared to conventional fertilization regime in lettuce (Reference = calcium ammonium nitrate (CAN; 27%N) as synthetic N) and maize (Reference = pig manure (PM) + CAN). N replacement use efficiency (NRUE) does not account for the effect of unfertilized treatment, whereas N fertiliser replacement value (NFRV) takes into account the effect of unfertilized treatment. To determine NRUE and NFRV of ammonium nitrate, the reference treatment is considered to be 100% effective.

Similar results were obtained during the field application of the produced ammonium nitrate in the WINGS project. During a pilot, ammonium nitrate was produced from the liquid fraction of cattle manure. This ammonium nitrate was applied on the fields of the cattle farmer, where he was growing grass as feed crop. The ammonium nitrate was applied by research institute Hooibeekhoeve, and the farmer got from Flemish minister Koen Van den Heuvel, the then Minister of agriculture and environment, an exemption to apply the ammonium nitrate as replacement for mineral fertilisers, above the limit for animal manure (170 kg N/ha). Hooibeekhoeve applied the ammonium nitrate as replacement for CAN (calcium ammonium nitrate) next to (liquid) raw cattle manure by means of an agriculture sprayer.

The results of this demonstration test show that ammonium nitrate can be used as a replacement for CAN and even results in better yields (Figure 9). It was concluded that further research on ideal application methods for AN is necessary. In this field demo a sprayer was used, but due to the rather low nitrogen concentration of the AN, the application speed of the sprayer was too low to be practicable.

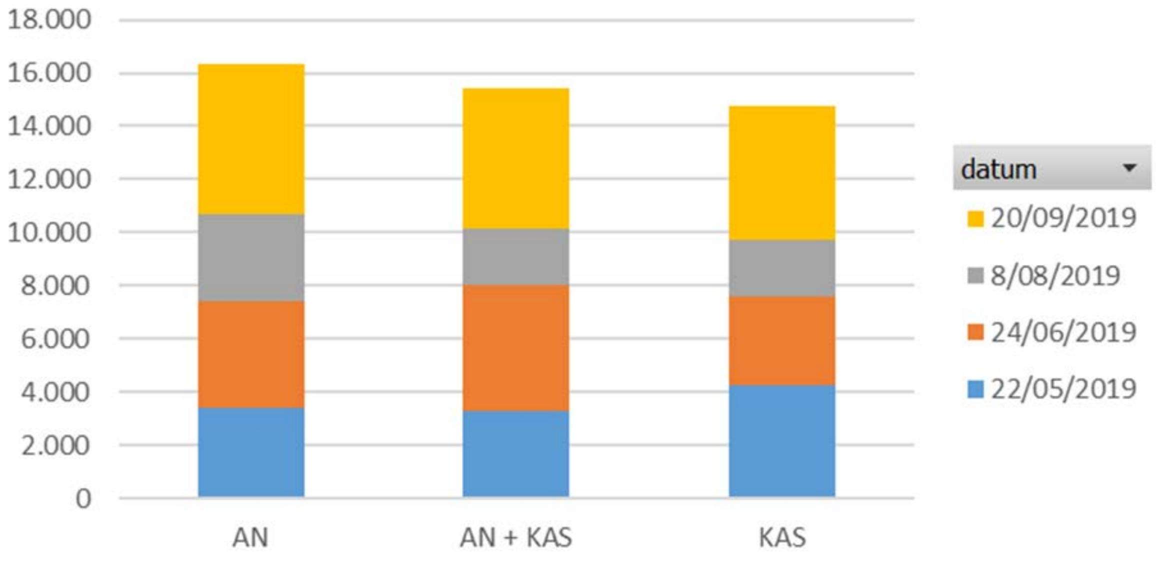

Figure 9 Yield (kg DS/ha) for three grass crops (2nd, 3rd, 4th and 5th crop). Dosing is based on a gift of 250 kg CAS/ha. AN: ammonium nitrate; KAS: Calcium ammonium nitrate.

7.2.4 *Environmental aspects*

Environmental aspects have been assessed in field experiments by measuring post-harvest nitrate residue in soil/water. The measured nitrate residue gives an estimate of the nitrate amount that can potentially leach to ground and surface water. This instrument is used in Flanders (Belgium) since MAPII.

Since the nitrate residue is measured on field scale, only results found from a field experiment with ammonium nitrate are reported (Figure 10). In maize trials (Biogas-e, 2016b), no significant differences were observed between the reference treatment and the treatment where ammonium nitrate was used as a N source (Figure 10). Both the reference treatment and Pig Manure + Ammonium Nitrate treatment were below the maximum allowable level of 90 kg NO_3-N ha^{-1} in 0 – 90 cm soil.

When AN was applied during the WINGS projects on grass together with cattle manure, higher nitrate residues were found in the level 0-30 and 30-60 cm soil compared to the reference (CAN + animal manure). Possibly the higher levels detected in the field demo of WINGS could be due to other factors such as the extreme drought and heat in the summer of 2019.

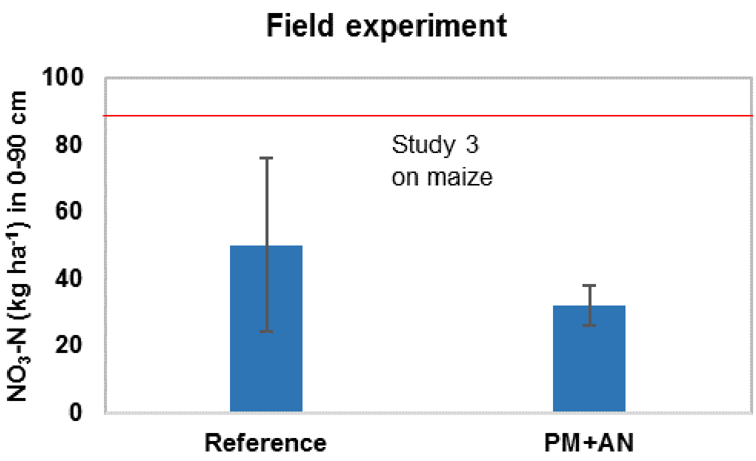

Figure 10 Effect of ammonium nitrate (applied in combination with pig manure) Study 3 on maize and conventional fertilisation (Reference 80 = pig manure (PM) + synthetic N) on post-harvest nitrate residue (kg ha-1) in 0-90 cm soil layer. The red line indicates the maximum allowable level of nitrate residue in soil (90 kg NO3- N ha-1) between October 1 and November 15 according to current Flemish environmental standards for maize cultivation in zones where measured NO3- concentrations in ground water do not exceed 50 mg NO3- L-1.

7.2.5 *Current legal view on ammonium nitrate*

The Nitrates Directive defines this product as animal manure and not as mineral N fertiliser. Therefore, the product has to fulfil the use requirements of animal manure, and therefore has to compete with animal manure (which has no, or even a negative, financial value).

In Table 9, the ammonium nitrate produced by a constructor who provided information for this note, is compared to the RENURE-criteria; it can be concluded that this ammonium salt (Category 1) most probably will be able to comply with these criteria. If not, the process circumstances can be adapted to comply with the criteria. This was also confirmed for ammonium nitrate (as well as ammonium sulphate) in the SAFEMANURE study (Huygens *et al.*, 2020).

Table 9 Average composition of ammonium nitrate (AN) from a providers who submitted a file for this document.

	kg N_{min}/ton	kg N_{tot}/ton	% DS	N_{min}/N_{tot}	Cu (mg/kg DM)	Zn (mg/kg DM)
AN	77,90	83,0	21,0	0,94	0,92-6,89	25,83-27,87

7.3 Files submitted for Category 1 (scrubbing salts: ammonium nitrate; ammonium sulphate)

Company	**Product (AS: ammonium sulphate, AN: ammonium nitrate)**	**Process (LF: liquid fraction)**	**Analyses**	**Status stripping scrubbing technology**
	AS	Stripping-scrubbing (manure)	**NA**	In engineering phase
	To be defined: • AN 10% or 18% N	Stripping-scrubbing (LF of digestate)	Analyses low and high concentration AN	Pilot installation operational
	To be defined: • AN 10% or 18% N • AS 8% N	Stripping-scrubbing (LF of manure)	Analyses low and high concentration AN	Permit being requested
	To be defined: • AN 10% or 18% N • AS 8% N	Stripping-scrubbing (LF of manure)	Analyses low and high concentration AN	Permit received
	To be defined: • AN 10% or 18% N • AS 8% N	Stripping-scrubbing (LF of manure)	Analyses low and high concentration AN	Permit received
	To be defined: • AN 10% or 18% N • AS 8% N	Stripping-scrubbing (LF of manure)	Analyses low and high concentration AN	Engineering phase
	To be defined: • AN 10% or 18% N • AS 8% N	Stripping-scrubbing (LF of manure)	**NA**	Permit being requested
	To be defined: • AN 10% or 18% N • AS 8% N	Stripping-scrubbing (LF of manure)	**NA**	Permit being requested
	AN (18% N)	Stripping-scrubbing (LF of digestate)	**NA**	In engineering phase
	To be defined: • AN 10% or 18% N • AS 8% N	Stripping-scrubbing (LF of manure)	**NA**	In engineering phase
	AN	Innovative combination of fysico-chemical processes (LF from digestate and manure)	Analysis of the scrubbing salts from the SATURN installation	In engineering phase

Next to the files mentioned above, VCM received information from other manure processers, farmers and constructors thinking to implement this technology. Therefore, it is highly likely that soon more files will be submitted for the application of scrubbing salts.

8 PRODUCT CATEGORY 2: Mineral concentrates

The information in this chapter is based on Hoeksma & de Buisonjé (2012) and fact sheets made up in the margin of the SYSTEMIC project. More elaborate information can be found in the accompanying brochure (Ehlert *et al.*, 2019).

8.1 Technology description

Mineral concentrates come from the processing of manure or digestate (Figure 11). The first step of the process is a solid-liquid separation by means of a decanter centrifuge, auger press or belt press. Coagulation and flocculation processes can be stimulated by use of polymers or flocculants. This leads to a solid fraction and a liquid fraction. The liquid fraction is processed further to remove particulate matter. DAF (dissolved air flotation units), microfiltration, ultrafiltration and nanofiltrations are technologies used to remove particulate matter. After filtration, the effluent enters a reverse osmosis (RO) unit (Figure 11). Water is pushed under high pressure through semipermeable membranes leading to a concentrate of minerals and a permeate (cleaned water). Fouling of the membranes by precipitation of salts, particulate matter that passed the filtration step and/or microorganisms requires regular cleaning and maintenance. The permeate can require an additional treatment by means of an ion exchange resin before discharging to surface water or the soil becomes possible. Initially mineral concentrates were obtained by a single reverse osmosis treatment step. In recent years, multiple (repeated) concentration steps have become more common.

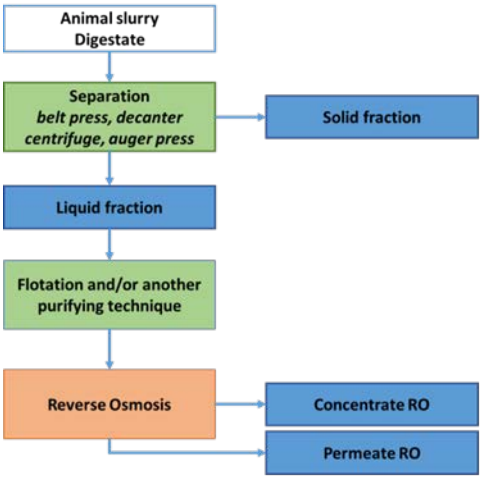

Figure 11: Example of a scheme for treatment and a photo of a reverse osmosis (RO) installation.

Figure 12: Samples of mineral concentrate of different reverse osmosis installations.

8.2 Product characteristics

Mineral concentrates (Figure 12) predominantly consist of ammonium-nitrogen (NH_4-N) and potassium.

Surveillance across ten pilot plants in the Netherlands showed that on average 90% of the Total Nitrogen of the mineral concentrates is NH_4-N. These values corresponded with a single RO concentration step (Table 10). The ingoing liquid fraction contains some organic matter which is present in mineral concentrates (1.3% organic matter or 0.6% C_{org}). Compared to pig slurry the ratio between NH_4-N to Total N increased from 66% to 90%. Currently studies are undertaken to increase the concentration by repetition of repeated cycles of RO.

Table 10 Average chemical composition of mineral concentrates (MC), fattening pig slurry, liquid (LF) and solid (SF) fraction of fattening pig slurry (Ehlert & Hoeksma, 2011; Velthof, 2015)

Parameter	MC	Pig slurry	LF	SF
Dry matter, g/kg	33.4	72.1	17.1	269.3
Organic matter, g/kg	13.3	51.1	7.8	203.5
Total N, g/kg	7.1	6.3	3.6	11.8
NH4-N, g/kg	6.4	4.1	3.0	5.2
NH4-N/Total N	0.9	0.7	0.8	0.4
P, g/kg	0.2	1.6	0.1	6.8
K, g/kg	7.2	4.1	3.4	3.6
Ca	0.2	1.9	0.2	8.7
Mg	0.1	1.0	0.1	5.0
S	1.1	0.7	0.6	2.9
Na	0.2	0.9	0.8	0.7
pH	7.9	7.7	8.0	8.2

8.3 Agronomic aspects

Agronomic effectivity of mineral concentrates has been tested under controlled conditions in pot experiments and in field experiments on arable land and grassland. Potassium is equally effective as mineral potassium fertilisers. The nitrogen fertiliser replacement values (NFRV) are given in Table 11.

Table 11 Nitrogen fertiliser replacement values[1] of placed or injected mineral concentrates (MC) compared with chemical reference fertilisers calcium ammonium nitrate (a) or liquid ammonium nitrate (b) in percent (%) compiled from several publications (Ehlert et al., 2019).

Experiment	Range
Pot experiment grass	86 – 96[a]
Pot experiment Swiss chard	87[a]
Field experiment arable land, potato	75 – 84[a]
Field experiment arable land, silage maize	72 – 84 [a]
Field experiment grassland	54 – 81[a]
	79-102[b]

[1] Nitrogen Fertiliser Replacement Value (NFRV, %):

$$NFRV = \frac{((\ N\ uptake_{mc} - N\ uptake_{control})/total\ N\ applied_{MC})}{((N\ uptake_{reference} - N\ uptake_{control})/total\ N\ applied_{reference}} * 100$$

The fertiliser value of the reference chemical fertiliser is set at 100% although this does not mean that chemical fertilisers are for 100% effective. To prevent ammonia volatilisation, mineral concentrates require shallow incorporation or need to be injected into the soil.

The lower values of NFRV, shown in Table 11, coincide with the earliest experiences with mineral concentrates. The higher values are based on more recent data. This points on a learning process of the production method and successful efforts to increase mineral nitrogen contents and a fine tuning of the application methods. NRFV depends on the chemical fertiliser used as reference. Under controlled conditions (pot experiments), nitrogen uptake efficiency of mineral concentrates is only slightly lower as calcium ammonium nitrate (NFRV is approaching a full replacement value of 100%). In the field trials however, NFRV values were more variable presumably due to atmospheric NH_3 losses. More research is needed on the effect of the application techniques on N uptake efficiency.

8.4 Environmental aspects

The environmental performance of mineral concentrates was assessed by looking at their effect on nitrate accumulation in soil, nitrate accumulation in groundwater, ammonia volatilisation and emission of greenhouse gasses.

There is no evidence that mineral concentrates increase nitrate concentrations in groundwater. In fact, relatively low nitrate values were measured in groundwater under fields fertilized with mineral concentrates as compared those receiving Calcium Ammonium Nitrate (CAN) or manure (Figure 13). Similar results were found in another 4-year field trial were no significant differences in nitrate concentration in soil of fields treated with mineral concentrates and those receiving manure or CAN were found (Figure 14).

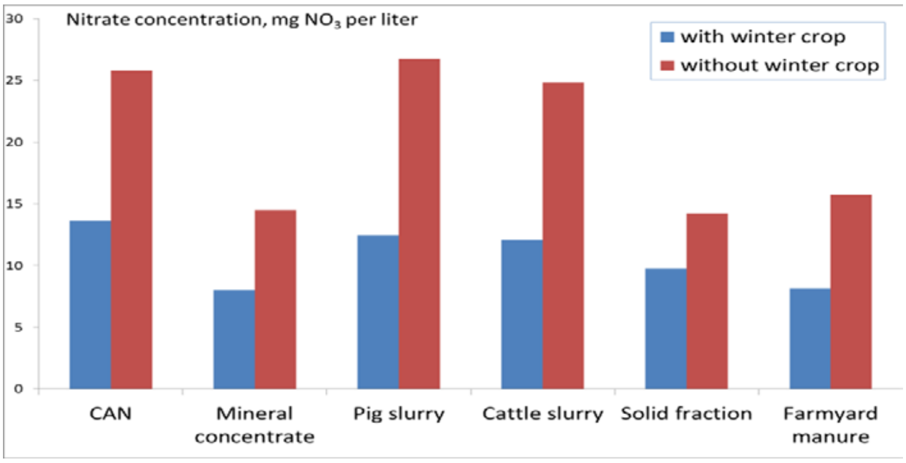

Figure 13 Average nitrate concentration (mg NO3—N/L in upper groundwater in a field experiment with silage maize for different fertilising products with and without a winter crop (Schröder et al., 2013).

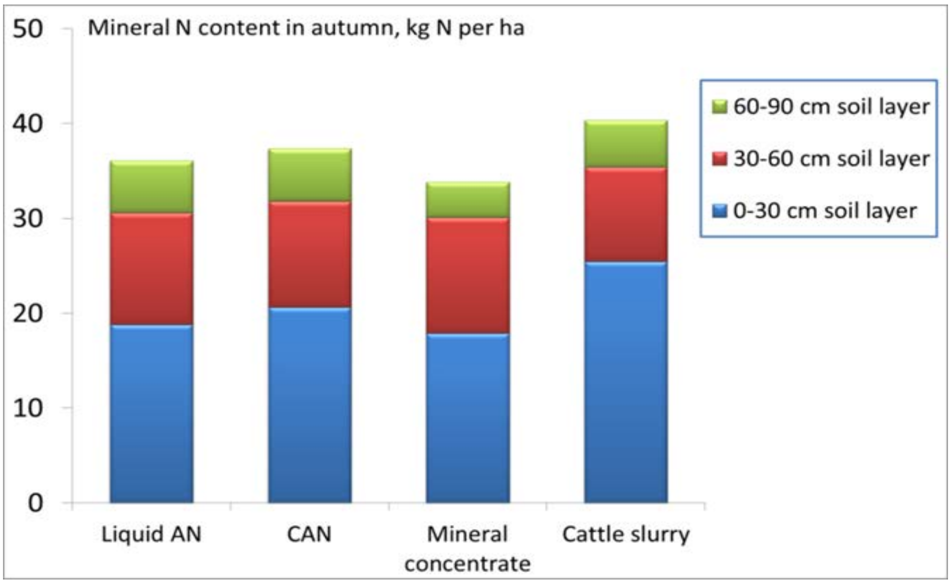

Figure 14 Average mineral N contents (0-90 cm soil layer) at the end of the season, grassland field experiments in the period 2009-2012 (van Middelkoop & Holshof, 2017).

Incorporation into the soil prevents ammonia volatilisation but enhances emission of the greenhouse gas N_2O due to denitrification (Figure 15). The level of N_2O emissions are between the levels of CAN (low) and urea (high).

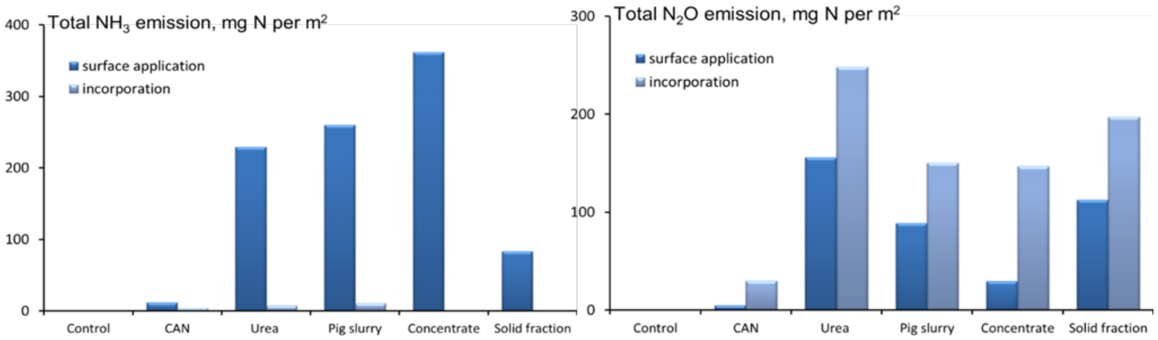

Figure 15 Average NH3 (left) and N2O (right) emission in a laboratory study with arable soil from calcium ammonium nitrate (CAN), urea, pig slurry, mineral concentrate (concentrate) and solid fraction. Fertilising products were surface applied or incorporated into the soil. Fluxes of NH3 and N2O were determined during incubation of one month, using a photo-acoustic gas monitor (Velthof & Hummelink, 2011).

Mineral concentrates showed under controlled conditions (e.g. pot experiment) a nearly similar agronomic effectivity as CAN but it’s effectivity is somewhat lower under field conditions. There is no evidence that mineral concentrates lead to a higher risk of accumulation of nitrate in soil or groundwater. Nonetheless, under field conditions attention has to be paid to the method of application. To prevent ammonia volatilisation, mineral concentrates need to be incorporated into the soil. N_2O emission caused by mineral concentrates are higher compared to CAN but lower when compared with the chemical fertiliser urea.

Overall agronomic and environmental performances of mineral concentrates is in line with chemical nitrogen fertilisers. Overall, N use efficiency of mineral concentrates is only slightly lower than of CAN and similar to that of LAN (limestone ammonium nitrate) under the condition that MC has been injected or acidified to reduce ammonia volatilisation. The technique of placement of a mineral concentrate requires fine tuning.

8.5 Current legal view on mineral concentrates

The legal status of MC differs from a synthetic (chemical) fertiliser. As a product recovered from manure, the legal status of MC is manure and thus has to fulfil the application rate standard of nitrogen of 170 kg N/ha.

In Flanders, mineral concentrate must compete with animal manure and has therefore no, or even a negative, financial value.

In Table 12, for an installation for which an analysis is available, the mineral concentrate composition is compared to the RENURE-criteria; it can be concluded that the proposed mineral concentrates (Category 2) most probably will be able to comply with these criteria. If not, the process circumstances can be adapted to comply to the criteria.

The potential of mineral concentrates to comply to the RENURE-criteria was also confirmed in Huygens *et al.* (2020).

Table 12 Average composition of mineral concentrate from a Flemish installation.

	kg N_{min}/ton	kg N_{tot}/ton	% DS	N_{min}/N_{tot}	Cu (mg/kg DM)	Zn (mg/kg DM)
	5,9	6,6	3,4	0,9	NA[1]	NA[1]

[1]VLACO certificate (keuringsattest): this mineral concentrate with DS >2% must comply to the VLAREMA legislation. Annex 2.3.1.A states that the mineral concentrate needs to have a copper content <800 mg/kg DM and a zinc content of <1500 mg/kg content, but mostly the concentrations are even lower.

8.6 Files submitted for category 2 (mineral concentrates)

Company	Product (MC: mineral concentrates, LF: liquid fraction)	Process (RO: reverse osmosis)	Analyses	Status reverse osmosis technology
	Mineral concentrate	Sieve press + Filtration processes and RO (LF from digestate)	**Analysis of MC**	Pretreatment and RO operational, MC is now being mixed with dried digestate
	Mineral concentrate	Sieve press + DAF + RO (LF from digestate)	**Analysis of MC**	Engineering phase
	Mineral concentrate	Sieve press + DAF + RO (LF from digestate)	**NA**	Pretreatment and RO operational, MC has a non-animal status as no animal manure is treated in this line
	Mineral concentrate	RO (LF from manure and digestate)	**NA**	Pilot operational
	Mineral concentrate	Ultrafiltration LF manure + RO	**NA**	Pretreatment and RO operational

Next to the files mentioned above, VCM received information from other manure processers, farmers and constructors thinking to implement this technology. Therefore, it is highly likely that soon more files will be submitted for the application of mineral concentrates.

9 PRODUCT CATEGORY 3: Liquid fraction of digestate

The information in this chapter is based on Sigurnjak (2020) and fact sheets made up in the margin of the SYSTEMIC project. More elaborate information can be found in the accompanying brochure (Ehlert *et al.*, 2019).

9.1 Technology description

The solid/liquid separation of digestate generates two outputs, the liquid and the solid fraction of digestate. The liquid fraction (LF) of digestate is represented by a pumpable liquid fraction richer in nitrogen. On the other hand, the solid fraction (SF) consists of some fibrous material rich in organic matter. There are several digestate separation methods such as belt press, sieve drum, screw press, sieve or decanter centrifuge (Figure 16). Furthermore, chemicals (i.e. flocculants and coagulants) can be used to improve separation efficiency. All these methods differ in efficiency in dry matter, N, P, or K portioning into liquid and solid fraction.

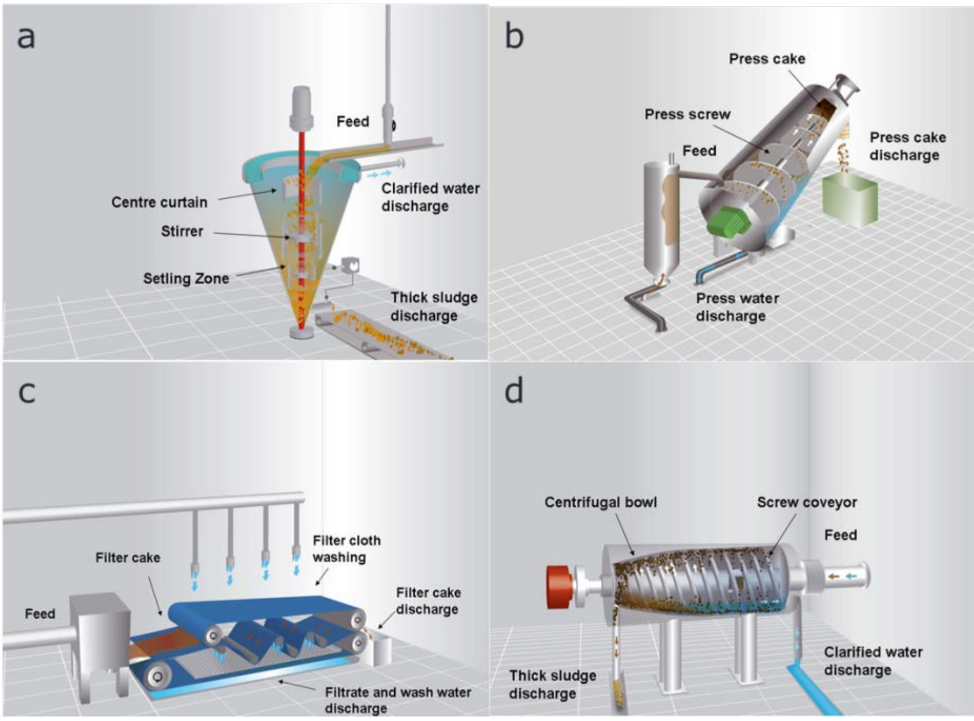

Figure 16 Examples of mechanical solid/liquid separators: a. thickener for sedimentation; b. typical screw press; c. typical belt separator with pressure rolls; d. typical decanter centrifuge (Hjorth et al., 2010).

9.2 Product characteristics

Literature reported (Akhiar *et al.*, 2017) a high range of variation of chemical, physical and biological characteristics of liquid fraction because of the type of solid-liquid separation along with the type of substrates used to feed the digester. Centrifugation and screw press with coagulant were the most efficient separation techniques, which resulted in the lower total solids concentration in liquid fraction of digestate. On the contrary, screw press only and vibrating screen were the least efficient separation techniques, which resulted in almost the same total solids concentration in liquid fraction of digestate than in the raw digestate. The origin of substrates, especially manure, seems to have major impact on characteristics of liquid fraction of digestates.

Table 13 reports the chemical characteristics of liquid fractions obtained from 13 Italian full-scale anaerobic digestion plants (Tambone *et al.*, 2017, 2019) and 11 French full-scale co-digestion plants (Akhiar *et al.*, 2017) where the feedstock consisted of different mix of pig and cow slurry, energy crops, agro-industrial residues, organic fraction of municipal solid waste and sludge.

Table 13 Chemical characteristics of liquid fraction of digestate samples. DM: dry matter; TOC: total organic carbon; COD: chemical oxygen demand; BOD_5: biochemical oxygen demand; TKN: Total Kjeldahl Nitrogen; TAN: total ammonia nitrogen; ND: not determined.

Parameters	Unit	A[1]	B[2]	C[3]
DM	g kg^{-1} FM	44.8± 9.3^a	42.9 ± 24.7^a	53.9 ± 34.5^a
pH		ND	8.1 ± 0.04^a	7.9 ± 0.3^b
Conductivity	mS cm^{-1}	ND	26.8 ± 8.1	ND
TOC	g kg^{-1} DM	358 ± 25^a	ND	384 ± 55^a
COD	g L^{-1}	ND	40.9 ± 25.1	ND
BOD_5	g L^{-1}	ND	4.8 ± 2.6	ND
TKN	g kg^{-1} DM	97.5 ± 19.4^a	ND	131.3 ± 122.6^a
TAN	g kg^{-1} DM	59.9 ± 20.3^a	ND	80.4 ± 75.5^a
TAN/TKN	%	59.8 ± 9.8^a	38.2 ± 14.3^b	60.5 ± 19.3^a
P_2O_5 tot	g kg^{-1} DM	37.3 ± 12.8^a	ND	31.9 ± 41.5^a
C/N		3.7 ± 0.7	ND	ND
Biological stability (OD_{20})	mg O_2 g DM^{-1} 20 h^{-1}	40.1 ± 15.1	ND	ND
Alkalinity	g L^{-1}	ND	16.5 ± 5.9	ND

[1] average of 13 samples (Tambone et al., 2017, 2019) obtained by screw separation
[2] average of 11 samples (Akhiar et al., 2017)
[3]average of 208 samples (European Biogas Association Database) obtained by different separation techniques.
Letters are referred to One-way ANOVA test (p<0.05, Gabriel post-test) applied for each parameter between the three groups of data (A, B and C)

9.3 Agronomic aspects

Riva et al. (2016) indicated that sub-surface injection of digestate and derived products at pre-sowing and topdressing, gave crop yields similar to those obtainable with the use of urea. Sigurnjak et al. (2017) found in a 3-year field trial that the liquid fraction of digestate used as a NK-fertiliser next to treatments with animal manure or digestate, showed similar effects on biomass yields and soil properties as the traditional fertilisation regime with animal manure and synthetic NK- fertilisers. In all the studies, yields obtained by fertilizing with liquid fraction of digestate showed no significant differences with those obtained with conventional practices (using only synthetic N or synthetic N in addition to animal manure). Finally, economic and ecological benefits were found to be higher when liquid fraction of digestate was used as a synthetic N substitute. Future perspectives indicate that nutrient variability in bio-based fertilisers will be one of the greatest challenges to address in the utilization of these products.

The use of the liquid fraction of digestate as a fertiliser in agriculture is a recent practice and so the available data are very limited in the literature. Currently, two papers have reported data on Nitrogen Use Efficiency (NUE) of liquid fraction of digestate used as a fertiliser, but unfortunately both have been carried out in pot experiments. The information extrapolated from the two works is shown in Table 14.

Table 14 Nitrogen use efficiency (NUE) of liquid fraction of digestate used as a fertiliser

Crop	N application rate	NUE (%)	Reference
Barley	300 mg N kg^{-1}	61	Maurer et al. 2019
	500 mg N kg^{-1}	47	
Lettuce	210 kg N ha^{-1}	62	Sigurnjak et al. 2016

The NUE values reported in Table 14 show variability depending on crop type used during the experiments (barley and lettuce), and above all to the amount of nitrogen dosed in the form of liquid fraction of digestate. The NUE values reported for the liquid fraction of digestate are however only slightly lower than those reported for conventional synthetic fertilisers. Sigurnjak and colleagues report a NUE value for liquid fraction of digestate of 62% which was somewhat lower than the NUE for calcium ammonium nitrate (CAN) which amounted to 71% (Sigurnjak et al. 2016).

9.4 Environmental aspects

Because of the origins of the matrices from which digestate and the relative fractions (liquid and solid) are obtained, i.e. animal slurry plus by-products and energy crops, heavy metals content and presence of pathogenic microorganisms must be considered.

Table 15 report the results of Tambone et al. (2017) on 13 samples of liquid fraction on principal heavy metals which are in line with the concentrations of poultry manure, sewage sludge and compost.

Table 15 Heavy metals content in liquid fraction of digestate in mg/kg dry matter.[1] Tambone et al. (2017) [2] *and European Biogas Association database.*

Metal	Liquid Fraction[1]	Liquid Fraction[2]
Ni	9.8 ± 4.8	10.4 ± 5.6
Zn	245 ± 117	361 ± 320
Cu	55 ± 27	90 ± 89
Pb	1.7 ± 0.8	78 ± 11
Cd	0.3 ± 0.2	0.4 ± 0.2
Cr	11.6 ± 6.3	12 ± 11

As example of ammonia volatilization during the utilization of digestate and liquid fraction of digestate is reported in Riva et al. (2016) in a short-term experiment, in which digestate products were used as substitutes for mineral (N) fertiliser in a corn cultivation. In brief, digestate and the liquid fraction of digestate were applied to soil at pre-sowing and as topdressing fertilisers in comparison with urea, both by surface application and subsurface injection. After each fertiliser application, ammonia emissions were measured. Ammonia emission data indicated, as expected, that the correct use of digestate and derived products, injected into the soil, avoided ammonia volatilization. Subsurface injection allowed the reduction of ammonia emissions to levels that were similar to those obtained by using urea.

Sigurnjak et al. (2017) carried out field trials in Belgium on maize crops, and measured the nitrate content in the soil at a depth of 90 cm after the harvest period. The nitrate concentration of the parcels fertilised with digestate liquid fraction was always slightly higher than the concentration measured in the control plots, fertilised with chemical fertilisers. However, the values do not exceed 75 kg NO_3-N ha^{-1}.

Also, in Belgium, Tsachidou and colleagues (2019) carried out a similar experiment on a grassland soil used for grazing. In this case, the concentration of nitrate at 90 cm depth for the parcels fertilised with digestate liquid fraction was always lower than that found at the same depth for the parcels fertilised with ammonium nitrate. Furthermore, it has been reported that by increasing the amount of nitrogen dosed from 230 kg ha^{-1} to 350 kg ha^{-1}, the concentration of nitrate detected at 90 cm depth in the parcels fertilised with ammonium nitrate has quadrupled, while no differences were found in the parcels fertilised with digestate liquid fraction.

These results strongly confirm our hypothesis that, in the short-term, digestate liquid fraction applied as the sole nitrogen source and at the maximum rate of 350 kg N ha^{-1} yr^{-1} do not increase the potential nitrate leaching risk in comparison to chemical fertilizers.

9.5 Current legal view on liquid fraction of digestate

When manure is digested during co-digestion, all digestates resulting from the process are designated as manure and thus they have to fulfil the requirements on use of the Nitrates Directive (91/676/EC).

In Table 16, for two installations for which an analysis is available, the liquid fraction composition is compared to the RENURE-criteria; it can be concluded that the proposed liquid fractions (Category 3) most probably will be able to comply with these criteria. If not, the process circumstances can be adapted in order to comply.

Table 16 Average composition of thin fraction of two Flemish installations.

	kg N_{min}/ton	kg N_{tot}/ton	% DS	N_{min}/N_{tot}	Cu (mg/kg DM)	Zn (mg/kg DM)
Company A	2,86	2,9	2,9	0,99	NA[1]	NA[1]
Company B	2,3	3	1,4	0,91	14,29	178,57

[1]VLACO certificate (keuringsattest): this mineral concentrate with DS >2% has to comply to the VLAREMA legislation. Annex 2.3.1.A states that the mineral concentrate needs to have a copper content <800 mg/kg DM, a mercury content of <1 mg/kg DM and a zinc content of <1500 mg/kg content, but mostly the concentrations are even lower.

9.6 Files submitted for category 3 (liquid fraction of digestate)

Company	**Product**	**Process (liquid fraction: LF)**	**Analyses**	**Status**
	Liquid fraction of digestate	Advanced separation process (LF digestate)	**Analysis liquid fraction**	Operational
	Liquid fraction of digestate	Advanced separation process (LF digestate)	**Analysis liquid fraction**	Operational

Next to the files mentioned above, VCM received information from other manure processers, farmers and constructors thinking to implement this technology. Therefore, it is highly likely that soon more files will be submitted for the application of thin fraction of digestate.

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ANNEX 1: Presentation of VCM vzw

The Flemish Coordination Centre for Manure Processing (Vlaams Coördinatiecentrum Mestverwerking) is an independent intermediary platform between the government and the manure processing sector.

The mission of VCM vzw is to support sustainable manure processing activities in Flanders, by informing the government and the sector on all aspects related to manure processing and stimulating and coordinating consultation. VCM vzw achieves this mission by performing the following main tasks:

- The initiation and coordination of structural and thematic consultations between the government and the sectors involved;
- Performing policy supporting work via a.o.:
  - Performing studies on certain themes such as innovative manure and digestate processing techniques;
  - Listing the bottlenecks concerning manure processing;
  - Analysing the evolution of the operational and available manure processing capacity in Flanders (VCM survey) per year.
- The development of a knowledge centre with regard to all aspects of manure processing, with a special focus on the maximum valorisation of nutrients from manure and residual flows in manure processing;
- General information transfer via brochures, website, electronic newsletter, social media, study days, webinars, press releases and visits to installations;
- International cooperation: through participation in European project activities (Interreg NL-VL NITROMAN, Horizon2020 Systemic, Danone Ecosystem Fund WINGS, ...), inform other member states with manure surpluses about Flemish manure processing, organization of an international conference on manure management and valorisation ManuREsource and participation in international exchanges;
- Informing all those involved by giving independent first-line advice on technological choices and to supply guidance and understanding in the various legislations with regard to recognition, processing obligation, transport, export and sale of end products;
- Organization of an award (Ivan Tolpe Prijs) for innovations in manure processing.

VCM is supported by a large variety of members (see below). Thanks to this structure, VCM can guarantee its independent position. More information on VCM vzw can be found on the English website https://www.vcm-mestverwerking.be/en.

A-members VCM

B-members VCM

Flemish biobased fertilizers recovered from manure complying to the RENURE-criteria

ANNEX 2: Projects and Platforms

This document builds further on the experiences gained during several projects. The logos / programs of these projects are summarized below. More information on the projects can be found in Chapter 6.

Projects/Platforms (running/finished) with VCM as partner:

MIP-ICON

Nutricycle

UNIR

Other projects (running/finished):