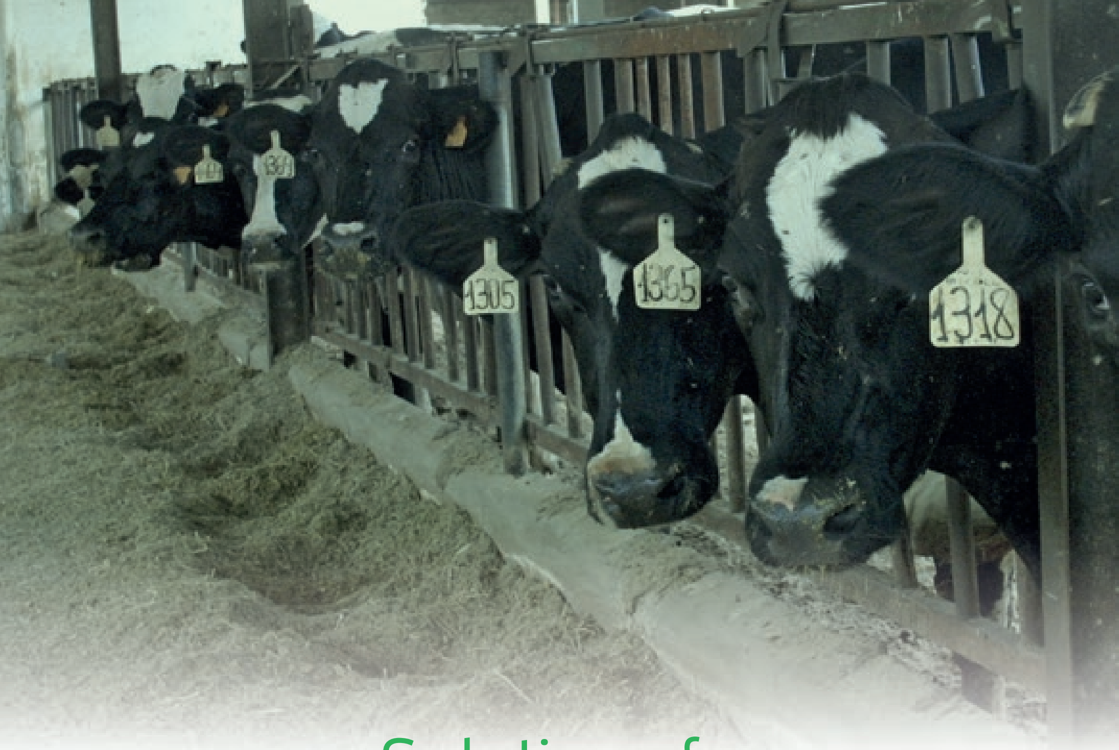

Solutions for manure surplus in the dairy industry

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This publication forms part of the WINGS project; a collaborative between Danone and VCM, supported by the Danone Ecosystem Fund.

Authors
Annelies Gorissen & Emilie Snauwaert (VCM)

Editors
Marion Bloemendal (Danone), Dirk Denorme (VLM), Philippe Tavernier (POM West-Flanders), Thomas Vannecke (VCM), Dieter Vanparys (Bio Armor), Liesbeth Verheyen (BFA) and Bart Verstrynge (KBC).

Responsible Publisher
VCM non-profit org (vzw), Baron Ruzettelaan 1 B0.3, 8310 Brugge
www.vcm-mestverwerking.be
T 050 737 772

Citation method
Gorissen, A. & Snauwaert, E. (2018) *'Oplossingen voor het mestoverschot in de melkveehouderij'*. Published by the Flemish Coordination Centre for Manure Processing (vzw) in Brugge.

Second edition, January 2019.

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1. Foreword

A survey conducted regularly by dairy company Danone among its dairy farmers, showed concerns about manure problems in 2014. Half of the dairy farmers indicated concerns about manure management as a barrier to continuity and growth of the dairy farm.

Given the limited land surface-areas available in Flanders, a challenging legislative framework and increases in production after the abolition of quotas in 2015, these concerns are of increasing importance.

This is why Danone, supported by the Danone Ecosystem Fund, decided to support its dairy farmers and the entire dairy sector in the search for sustainable solutions for surplus manure. Thanks to collaborations with the Flemish Coordination Centre for Manure Processing (VCM), the WINGS project was commenced in 2016.

This manual about manure processing is a tangible result of this 3-year intense collaboration. It combines both already known, established manure processing techniques as well as more innovative techniques of recovery of nutrients such as nitrogen or phosphorus. Before entering into discussion of the different techniques, some important observations are made first; namely, the specific characteristics of cattle manure, the need for manure processing permits or licences, the importance of scale and possible workloads. A deliberate choice was made to divide the techniques on the 'building blocks' principle, so that they can be combined together to achieve a total process as may be preferred. The third part of this manual discusses legislations and subsidy options. In the conclusion, more information can be found about the WINGS project.

Both Danone and VCM wish you much success with your manure processing project in advance. We hope that this manual provides you with a source of inspiration, help you with your preparations and provide practical tips on how to achieve successful outcomes.

Jurgen Berckmans — Dirk Denorme

Danone — VCM

2. Introduction

It seems hard to imagine these days, but until the twentieth century there was a shortage of manure. Increased numbers of livestock, partly due to the increasing use of feed concentrates, tractors and automatic milking machines, are the main reason for growing supplies of manure.

The Flemish Manure Policy originated in 1991 as a result of the introduction of the European Nitrates Directive (91/676 EEC). The Nitrates Directive aims to protect groundwater and surface water against nitrate leakage from agricultural sources.

From the inception of the manure policy, the major focus has been on the use of fertilising standards to control manure application on the land. The best-known standard is maximum administration of 170 kg of nitrogen from animal manure per hectare per year. In 2010, a nitrogen production of 187 kg[1] for every hectare of land was available. It is therefore obvious that more manure is being produced than can be applied.
Nevertheless, manure balance since 2008 has maintained equilibrium. Therefore, there is no longer a manure surplus at sector level. Manure processing constitutes the closing factor of the gap between production and demand. What cannot be used on agricultural land is processed into airborne nitrogen or finds its way abroad (after processing), to parks or private gardens. In 2010, about one-fifth of all manure produced was processed and it is expected that this important process will increase in the future.

In absolute figures for Flanders, 44.1 million kg of nitrogen (N) from animal manure (incl. export) was processed in 2017. The largest part (almost 85%) of nitrogen processing was done in 2017 by the processing and export of pig manure (a total of 18.9 million kg N or 42.8%), together with the processing and export of poultry manure (a total of 18.4 million kg N or 41.7%). Biothermal drying (mostly of poultry manure, horse manure, solid fraction of pig manure and solid fraction of cattle manure) is the most commonly applied technique for processing nitrogen (14.8 million kg N or 40%), combined or not combined with drying and granulating. A similar amount of nitrogen (13.1 million kg N or 35%) is processed through biological processing of the liquid fraction (of pig manure, cattle manure or digestate), with or without post-treatment in constructed wetlands.

[1] Van der Straeten B. & Buysse J. (2013) Vraag naar mestverwerking onder MAP IV, Beleidsdomein Landbouw en Visserij, afdeling Monitoring en Studie, Brussels.

However, technological development is not static. In 2017, the first full-scale plant for nitrogen recuperation from the liquid fraction of pig manure was licensed via stripping & scrubbing. The transition from manure processing to a circular economy, with a focus on nutrient recuperation, seems to have come out of the starting blocks. The closing of the nitrogen cycle was also included in the European Circular Economy Package and in the Flemish Agriculture and Fisheries Policy Paper 2014-2019 (Vlaamse Beleidsnota Landbouw en Visserij 2014-2019). Regarding manure processing, the transition to a circular economy with nutrient recuperation, can further ensure that:

- Manure processing products will replace artificial fertilisers;
- Import of finite sources of nutrients such as rock phosphate will be reduced;
- New natural resources (proteins, fibre...) will be produced from manure;
- Organic carbon in manure is valorised on our own Flemish agricultural soils.

It is of crucial importance for manure processing to permanently ensure that the Flemish manure surplus is managed in a judicious manner in order to prevent the loss of nutrients from agricultural sources.

Part I:
Draw the line

1. What makes cattle manure unique?

Cattle manure is characterized by a relatively low nutrient content and a high organic matter content compared to pig manure. The latter might just be the reason why cattle manure is more desirable nowadays in arable farming. A healthy, fertile soil provides the basis for sustainable crops and healthy food. Availability of organic (carbon) substances in the soil is important for improving soil structure, reducing soil erosion, increasing moisture-retaining capacity (and thus also climate adaptation), activating microbial life, the supply of nutrients and reduction of nutrient washout.

However, in manure processing plants, the higher organic matter content of cattle manure can present a problem. Fibres quickly clog the equipment. Proper and thorough separation is therefore important, especially in the more high-tech manure processing techniques. In addition to fibres, a higher viscosity sometimes also creates problems. The liquid fraction after manure separation often seems to be more viscous or slimy compared to the liquid fraction of pig manure.

It is obvious that rationing has a major effect on manure composition. Companies that use high feed efficiency can expect lower nutrient content in manure. For some techniques, the ratio of ammoniacal nitrogen to total nitrogen can also be important. This ratio is also lower in cattle manure than it is in pig manure.

Most manure processing techniques have been developed for use on pig manure. Pig farms are often not land-based and buy their feed externally. Consequently, the manure produced must be disposed of externally or processed. Assuming that techniques that work well on pig manure can also be applied equally well to cattle manure, shortages seem to have turned the corner.

Table I: Average composition of cattle manure compared to pig manure according to the 'Bodemkundige Dienst Van België' (Belgian soil specialist service) (EOC: Effective Organic Carbon is the amount of carbon still present in the soil one year after application and thus contributes to organic compound accumulation)[2]

	Average content (kg/ton)					
	EOC	N_{tot}	N_{min}	P_2O_5	K_2O	MgO
Cattle manure	15	3.8	2.0	1.3	4.1	1.0
Porcine manure	10	5.9	3.8	3.6	4.4	1.8
Porcine manure (slurry bins)	11	6.9	4.4	4.1	4.9	2.2

TIPS:

- Know your manure! Know the input source road you are taking. Compare manure analyses of the previous period to know what manure content you are dealing with.
- Ask a constructor or supplier about their experience with cattle manure and if any, what adjustments were made to the installations. In the case of no previous experience with cattle manure, can they do a test with an existing installation?

[2] Vannecke, T. et al. (2018) Literature search: Waarde van de dikke fractie na mestscheiding als bron van organische stof. Published by the Flemish Coordination Centre for Manure Processing (' Vlaams Coördinatiecentrum voor Mestverwerking' vzw) In Brugge.

2. To treat or to process? A licencing difference.

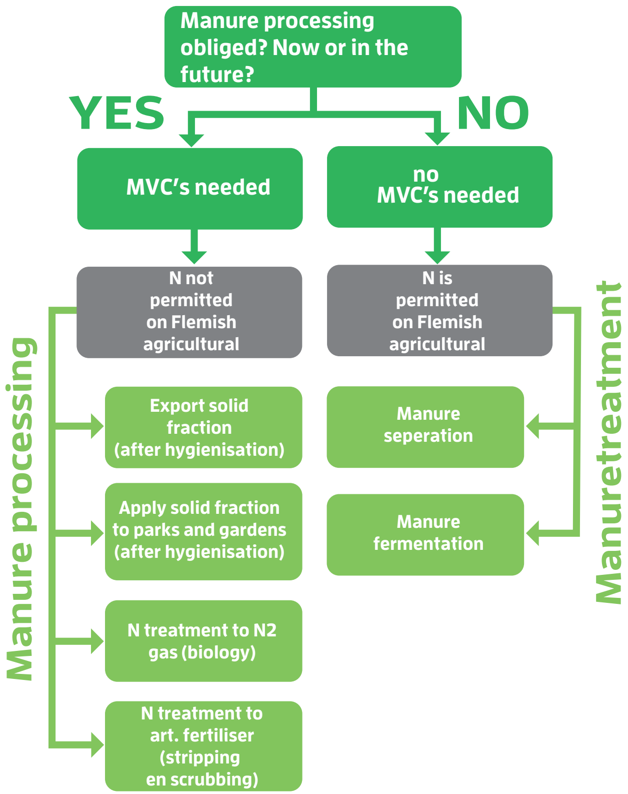
Since the second Manure Action Plan ('MestActiePlan') or MAP II, the manure processing-obligation policy has also been created. If more manure is produced on your farm than you can apply to your own soil, you are obliged to have part of this surplus processed. The basic processing obligation is calculated from the amount of manure surplus and based on the manure management pressure of the municipality involved (the amount of nitrogen produced per hectare). This basic processing obligations only apply to farmers who have a quantity of nitrogen to be processed that exceeds 5 000 kg.
One of the options for meeting manure processing obligations is to obtain **manure processing licence (MVCs).** You can only be awarded manure processing permission if you effectively process manure according to the definition in the Flemish Manure Decree ('VlaamseMestdecreet'); namely by:

- exporting (= outside of the Flemish Region) poultry manure or horse manure;
- exporting animal manure other than poultry or horse manure, based on explicit and previous approval by the correct authorities of the country or region of destination;
- treating the animal manure or other fertiliser, after which the nitrogen and phosphorus present in the animal manure or other fertilisers undergo one of the following processes:
  - *nitrogen is not applied to farmland in the Flemish region, except in gardens, parks and flower beds;*
  - *nitrogen is converted into nitrogen gas;*
  - *nitrogen is used in artificial fertiliser.*

Manure processing permits are awarded by the Manure Bank for the amount of nitrogen from Flemish animal manure that was processed by the manure processing installation.

In summary, we can propose that manure processing means that the nutrients (mainly nitrogen) are not applied to Flemish agricultural soils.

In Flanders, biological manure processing and biothermal drying (composting) with export are most common. Manure separation and fermentation are examples of manure **treatments**. The end products, that still contain the nutrients from the manure, are applied to the Flemish agricultural soils. Thus, you cannot obtain a manure processing permit or licence for this and you are therefore not meeting the manure processing obligations.



TIP:

- Liquidk carefully about what your manure surplus will be like now and in the future. Do you have a manure processing obligation already or will you have this in the future? Is nitrogen or phosphorus the limiting nutrient in your manure management record keeping?

3. Size does matter

Before you start a manure processing project, you need to know first how much manure you want to and can process. It is important to have an adequate and constant influx of manure all year round. Therefore, calculate your actual manure volume. Afterall, there is a large difference in volumes based on a manure production figure and the actual volumes. Manure production depends on milk production and water consumption. More milk = more manure. Top dairy cows that produce 12 000 kg of milk/year have a manure production of 37 to 39 m^3/year. Differences of 5-10 m^3/cow are therefore no exception.

Table 2: Manure production per average animal present (Handbook of dairy farming, 2006)

Manure production per average animal present (Handbook of dairy cow industry, 2006)	
Milk and calf cows (day and night stabling and feeding with conserved raw feed)	**Manure production (m^3/year) by ration 50 % grass silage and 50 % corn feed**
6 000 kg milk/cow	18.8
7 000 kg milk/cow	20.9
8 000 kg milk/cow	24.0
9 000 kg milk/cow	29.6
10 000 kg milk/cow	35.6

Do you have enough fertiliser on your own property or do you need to obtain more from a third party? If you want to process manure from other farming properties as well, you need to apply for a **Licence according to VLAREM-section 28.**3 ('Processing of animal manure') before processing manure from third parties. More information about this relevant legislation can be found in 'Part III: The rules of the game'.

One option to ensure that your manure processing project gets enough manure supplies is to start up a **cooperative or other form of collaboration** with fellow farmers. In the past, many pig farmers have started a cooperative with organic manure processing. However, it is often challenging to engage livestock farmers for 10 years to have a certain annual volume of manure processed at a predetermined price. A second example is a group of dairy farmers who buy a mobile manure separator together. The golden rule is always:

Good agreements make good friends. So, ask your adviser to draw up a cooperation agreement or contract. This includes provisions relating to maintenance costs and usage fees, the duration of the agreement, contractual dissolution options and user obligations such as only separating one's own property manure, keeping a register, mandatory cleaning of the installation, etc.

Instead of investing money yourself, you can also rent a **mobile installation**. A well-known example is the mobile manure separator but other techniques are now also becoming available as mobile equipment. This has the added advantage of allowing you to start manure processing or treatment on a small scale and with minimal risk and thus, to gain experience. In addition, mobile techniques can be engaged to do primary, decentralised preparations of manure. Please note: a mobile manure separator must also be licensed by having an environmental licence.

The more complex the technology, the less suitable it will be for use on a **farm scale**. On the one hand because specific and thorough technical knowledge by the operator is required. And on the other hand, because the installation often needs to process large quantities (order of magnitude 60 000 tonnes of manure slurry/year) in order to be economically viable. Purification to dischargeable water is a typical example of this and is only used in large, central manure processing plants.

A major process-speed inhibitor for larger manure processing projects is often the acquisition of the **environmental licence or permit**. Take plenty of time to liquidk about, possibly together with a consultancy firm, your communication strategy with the authorities and the nearby community. Who are the stakeholders and what is your relationship status with them? Have there been many complaints in the past? A commonly voiced fear in connection with new manure processing projects is potential odour problems and the fear of more transport activity. Therefore, anticipate any objections that could be raised and prepare your possible responses to these. The level of demand for manure processing is not the same everywhere in Flanders and it depends partly on **future developments in the manure management** policy. Stricter fertilising standards, and therefore a greater manure surplus will lead to increased processing needs.[3] According to research, the possibility of abolishing the derogation appears to have the greatest impact on processing needs. Although these trends are

[3] VanderStraetenB.&BuysseJ.(2013)'VraagnaarmestverwerkingonderMAPIV',Policy domain Agriculture and Fisheries,Monitoring and Study Department,Brussels.

difficult to predict, it is advisable to anticipate this as a possibility as much as possible.

TIP:

- What scale size is realistic for your business and your environment? More is not always better.

4. How much does it cost?

In order to be able to answer question about whether or not a particular manure processing technique is economically viable, you must firstly know **how much manure demand costs are at the moment (and will be in the future)** for your company. Therefore, look at the average over several years and take into account the estimates for subsequent years. Besides euros, other factors can also play a role; for example, the ease of manure distribution because for example, you may just need to make one phone call to the contractor and he will handle everyliquidg else. How much do you liquidk this is worth to you? Or, are manure sales actually quite protracted, which means that you could save time by doing more yourself? Alternatively, do you want more certainty about your manure sales (costs) in the future and more autonomy so that you are less dependent on third parties?

Descriptions of various techniques will specify a target cost for each one. However, the final **investment and processing costs are heavily dependent on the individual company.** Therefore, take into account any hidden costs such as infrastructure works, storage, customised electricity connection, sampling, licencing procedures, etc. To be able to compare techniques and suppliers, you can summarize the costs in tabular form as seen in the example below.

Investment costs	
Acquisition technique	
Financing costs	e.g. 2 % interest
Other investment costs	Paving, pumps, hangar, storage of intermediate and final products, electrical connection, technical area, air purification
Operational costs	
Annual maintenance	Usually 5 % of more of acquisition costs
Personnel costs	Average 25 euro/hour
Average 25 euro/hour	e.g. polymers, filters, acids, glycerol, lime, ...
Analyses and policy making	e.g. FPS-Exemption,analyses,permit alternative hygienisation protocol,...
Electricity	Average of 0.186 euro/kWh
Water	Average of 4.3 euro/m³
End-Product sales costs	e.g. 25 euro/tonnes of solid fraction, 4 euro/tonne effluent...

Revenue	
Subsidies	e.g. VLIF, investment support, ...
Income from manure processing for third parties	e.g. 17-18 euro/tonnes of slurry waste for a biological manure processing installation
Sales of end products	

TIPS:

- Have you received an interesting quote? Request **a one-on-one** meeting to discuss this quote in detail.
- To get a good deal, **thorough preparation** is most important! Make up a 'cheat sheet' with any arguments you wish to address, clearing the table and asking the person in question to come to an appointment are a good start.
- Before you start negotiating, you need to set **your goals and boundaries.** Consider what you would prefer to achieve and the point to which you are willing to go. Good negotiators regularly break off negotiations and dare to push the pause button. This lets you maintain emotional distance and consciously put everyliquidg in clear order.
- Also try to make use of **non-verbal signals**. Make eye contact and hold a pen, because nerves are often distracted by hand movements. Show that you are confident and relaxed.

5. Who, oh who?

A question that is often not asked enough in the preparation stage of a manure processing project is: 'Who is going to run the installation?'. A more automated machine requires less labour. But the more high-tech the installation, the more technical or chemical knowledge the operator must have. Safety procedures also deserve the necessary attention. Do you own the **necessary knowledge** or do you need to employ someone for this, either from wiliquid the company, the family or externally? Please note that this means extra costs.

Not only is the necessary knowledge required, but **sufficient time** must also be made available. It is an illusion to assume that a manure processing plant will run flawlessly from the very first minute. Depending on the robustness of the technique, you must also be able to intervene promptly at times of malfunctions and defects. Does this form of permanence clash with other farming activities?

Some suppliers also offer **maintenance contracts**. This can be a good solution for outsourcing certain tasks. Consider in advance what you expect from a maintenance contract and any technical support. Prepare SMART objectives for this and have them included in the contract:

- **Specific** - Is the objective clear/specific?
- **Measurable** – By which (measurable/observable) criteria or form is the objective achieved?
- **Acceptable** – Are these objectives acceptable to both parties?
- **Realistic** - Is the objective achievable?
- **Time specific** – When (in terms of timeframe) should it be achieved?

For example: Don't say ' the installation needs to work properly', but do say: 'after a start-up and establishment period of 10 working days, the stripping and scrubbing technique will remove 80% NH_4-N from the liquid fraction and will contain a formed ammonia nitrate level of 15% N'.

The so-called **lean management** lets you organise company work processes more efficiently. The term 'lean' often refers to the elimination of waste. There are 8 different types of such waste:

- **Transport** - Unnecessary transportation of materials and products; vehicles driving around empty;
- **Supplies** – Stocking too many raw ingredients, materials and products (extra storage space also costs money);
- **Movement** – Employees walking, bending, rotating and reaching unnecessarily or excessively (e.g. while looking for materials);
- **Waiting** – Waiting for materials, people or information;
- **Overproduction** – Making too many products, too soon, or of too high a quality;
- **Unnecessary work** – Performing more processing steps than is necessary;
- **Defects** – When someliquidg is not right, you need to remedy it by fixing the cause of the defect for example;
- **Talent** – Not using the knowledge and skills of everyone who works for the company

Lean management reflects a philosophy through which you are constantly looking for improvement in the company. Improvements in processes to make everyliquidg run more smoothly, become easier and more efficient and to avoid waste. The biggest need in agriculture and horticulture is standardisation. In farming, there are many liquidgs that you cannot always control, such as the weather, the soil... This is why we tend to forget that there are also many issues that we can control. By optimizing these, you create more time to pay attention to all of the issues. Everyliquidg is easy to find in a well-organised business. Prompt repair of broken machinery also forms part of the lean management philosophy.
More information about lean management can be found at:
www.innovatiesteunpunt.be

TIPS:

- Arrange for maintenance contracts to be checked by a legal expert. Include SMART objectives, such as a minimum time response for technician services in case of breakdowns.
- Maintenance contracts often only cover 2 to 3 years. However, from the outset, also arrange a follow-up contract to avoid sharp price increases when the contract ends.
- Together with suppliers, create a clear overview of what tasks are to be performed daily/weekly/yearly and what problems may occur.
- Visit existing or similar manure processing plants and ask specific questions about their workload.
- Check any parts that need to be replaced regularly, that are specific to a particular brand or readily available on the market. This action can lead to significant cost savings.

6. What do I do with the end products?

In an ideal world, you use your manure processing plant to produce (fertiliser) products for which the whole world is waiting. Unfortunately, reality is often quite different. Some techniques produce products that are difficult to sell. This means that the problem is being shifted. Obviously, you should try to avoid this. Ask the supplier **which end products** exactly are to be made, to what specifications (demand analyses and one is not enough!) and what he believes the sales outlets and prices to be. Also check in your region who else is putting similar end products on the market and which markets they are targeting. Is there room for an additional installation? Is marketing of the end products a cost or a gain? Are there periods when sales are impossible causing the need for you to provide extra storage space? What effect do the end products have on your own business- and fertilisation strategy (e.g. unwanted drainage of organic matter)?

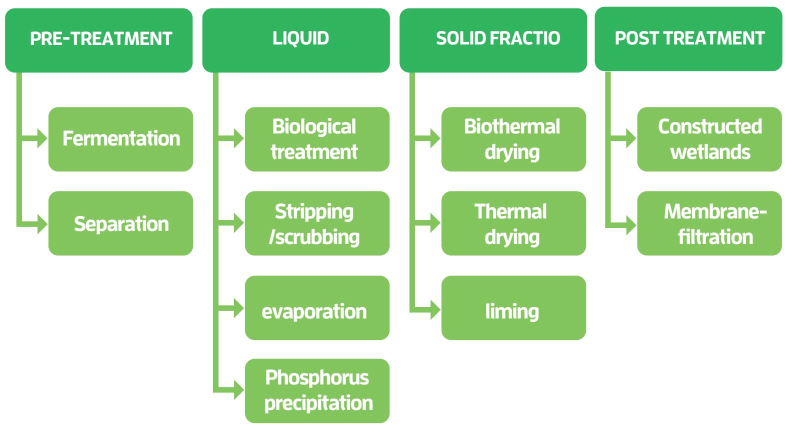
Legislation also plays an important role here. These days, the Nitrate Directive stipulates that all products produced from manure still carry the 'animal manure' statute. This means that, to sell these products there is always ongoing competition with widely available raw animal manure. Only water (ammonium sulphate) from chemical air scrubbers for air purification in stables is the exception to this rule as this is classified as fertiliser in Flanders. If you also want to sell on to individual customers, garden centres, etc., the product must be sanitised or hygienised first. This means that the product must have been treated for 1 hour at 70 °C or the equivalent to kill any harmful bacteria. More information can be found in 'Part III: the rules of the game'.

TIPS:

- Do a market research analysis about distribution channels for the end products.
- As much as possible, produce according to customer demand: fertiliser/manure by demand.

Part II:
Techniques for manure processing and -treatment

In most manure processing projects, different techniques are combined. Therefore, this manual uses a classification based on 'building blocks' so that a pre-treatment can be combined with a technique on liquid and/or solid fraction and finally involve a post-treatment. Keep in mind that the more techniques are combined, the more difficult the process will be and the more important it will be to coordinate the different techniques properly.



A number of manure processing techniques are not mentioned in this publication because they are not applied in Flanders; for example, combustion and pyrolysis (gasification) of manure. These techniques are not in line with the Flemish Materials Decree, as these convert the organic substances in manure into carbon dioxide and therefore destroys them.

Every technique is discussed in the context of how it works, what the end products are, its associated costs and any possible important points. Note however, that there are many differences between similar installations, such as pre- and post-techniques, location, operation, capacity etc. so that processing costs may vary considerably. In what follows, only a target price is provided so that you can get an idea about costs involved. You will obviously need to work out a comprehensive cost simulation for your own specific situation based on the quotations you receive from various manufacturers. Arrange support from a consultant and calculate several detailed scenarios.

Furthermore, techniques will evolve over time and this manual only offers a snapshot. You can always contact VCM for first hand advice.

I. Pre-treatment

i. Fermentation

How does it work?

Fermentation is an anaerobic process (in the absence of oxygen), during which microorganisms break down the biomass. Due to carbon degradation, **biogas** is formed, which mostly consists of methane and carbon dioxide. Biogas is used in Flanders as a renewable fuel for running a CHP, whereby the biogas is burned in a gas engine and electricity and heat is produced. This heat can be used to keep the reactors at the right temperature or for other business uses, for example for warming up rinsing water at the milking plant or for drying the digestate. Other future possibilities for biogas use are to upgrade it to natural gas quality (for addition to the gas grid as green gas) or to purify and liquefy it (to produce Liquefied Biogas).

Different input streams can be used for fermentation: organic biological waste (OBAs) and/or manure. A combination of manure and OBAs is referred to as 'co-fermentation'. When manure only is fermented, the term 'mono-fermentation' is used.

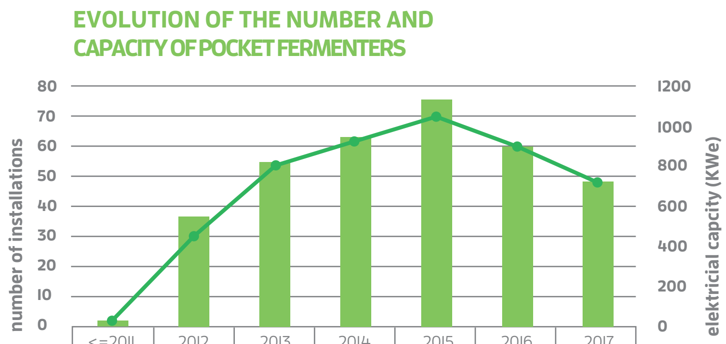
Pocket fermentation

Although there is no legal definition of pocket fermentation, it is generally accepted that it involves installations that are fed by local proprietary biomass for business owner energy demands. Electrical capacity is up to 200 kW and the fermented amount of fresh biomass is up to 5000 tonnes per year. Installations with a capacity of less than 10 kW are also known as micro digesters. The proprietary character of pocket fermentation is what makes technology so different compared to large-scale fermentation.

In pocket fermentation, manure is brought straight from the manure cellar to the fermenter, in which pocket digestion can potentially provide greenhouse gas emission reductions in manure storage.

In Flanders, about 80 farmers have invested in so-called pocket or micro-fermenters on their farms. These are used for mono-fermentation of cattle manure. Most pocket installations have a power output of around 10 kW. This corresponds to around 60 000 kWh on an annual basis, depending on the number of hours of operation.
A complete overview of suppliers and constructors can be found at **www.enerpedia.be**, click on 'Energy production' > 'Mest' (manure) > 'Pocketvergisting' (pocket fermentation).

Figure 1: Evolution of the number and capacity of pocket fermenters in Flanders. (The Flemish Biogas sector in 2017, Progress Report Biogas-E vzw)



	<=2011	2012	2013	2014	2015	2016	2017
number	2	37	55	64	76	61	49
capacity	40,7	448,3	810,2	926,6	1054,6	881,0	725,4

Large scale co-fermentation
The majority of large fermenters are co-fermenters: This means that they take a combination of manure, energy crops, vegetable and/or animal waste. As soon as one drop of manure enters the installation, the digestate must be managed as animal manure, which often means high costs. In co-fermentation plants, one depends on external price fluctuations on the biomass market. Also, the larger installations are subject to low market fees for the amount of electricity being injected.

End product characteristics

What remains after fermentation is called 'digestate'. Digestate contains lower levels of organic matter (decrease to 80%) due to the breakdown of volatile organic fatty acids. Fibrous material (lignin, cellulose) stays in the digestate and thus contributes to the soil-improving quality of the digestate. Organically bonded nitrogen is released as ammonium ($NH4^{+}$)

and is absorbed immediately by the plant. Phosphate content, as well as heavy metals content, remains unchanged. Fermentation is therefore not a processing technique in itself, because the digestate still contains all of the nutrients (N, P, K) that were originally present in the input streams. The digestate must therefore undergo further treatment in order to comply with the definition of manure processing.

Due to a higher ammonium content and a higher pH (degradation of volatile fatty acids), the risk of nitrogen volatilisation and leakage loss is greater than in non-fermented manure.

Table3:Composition (inkg/tonne)of cattle manureanddigestate after mono-fermentation(presentation byAnkeDe Dobbelaere (Inagro) at pocket fermentation workshop in 2014, based on 10analysis results)

	DM	OM	N_{TOT}	N_{MIN}	P_2O_5	K_2O
Cattle manure slurry	98.3	75.4	4.31	2.07	1.6	4.33
Digestate	65.4	46.9	3.91	2.46	1.4	4.33

From this, several conclusions can be drawn:

- Digestate contains approximately 30% less dry matter (DM) and organic matter (OM) than animal manure. It is the fast-degradable OM that converts to biogas. The EOC content, which is the carbon content that is still present in the soil after 1 year and thus contributes to carbon build-up in the soil, remains roughly the same.

- Digestate contains about 20% more mineral N. In order to avoid volatility, digestate can therefore best be injected. It may also be interesting to fertilise with digestate even in the autumn instead of using manure slurry, because of a less prolonged after effect (nitrate residue!).

The customers for digestate are currently the same as those for pig and cattle manure. Field trials show that digestate has a higher nitrogen effect, which can lead to a reduced fertiliser effect. A two-year field trial with digestate of cattle slurry on grass found that fertilising with digestate only led to a similar or slightly higher yield compared to cattle slurry[4].

[4] Schellekens, A. & Latré, J. (2014). 'Strategieën voor graslandbemesting'. LCV.

Costs of pocket fermentation

A pocket fermenter costs about 95000 euros. Installation for the use of heat being produced costs an average of 4000 euros. In addition, annual maintenance costs are 3000 euros. On average, pocket fermenter costs are calculated to have a financial return on investment period of 5 to 7 years, depending on how many adjustments are needed to the existing infrastructure.

Profitability of a pocket fermenter is strongly business dependent: electricity demands, heat requirements and profile, available fermentable flows, quality of the manure, presence of external manure storage, etc.

For more information, go to **www.biogas-e.be or www.inagro.be**

Points of attention for pocket fermentation

Everyliquidg starts with having quality manure available. If too little energy is obtainable from the manure, it does not make much sense to invest in a pocket fermenter. A number of constructors therefore provide manure analysis beforehand to test biogas potential. There are a number of measures that can be taken to promote the quality of manure:

- **The fresher the manure, the better it is.** Fresh cattle manure can deliver a biogas volume of 48 m³/tonnes, after a few days, this is only 35-38 m³/tonnes and after 1 month, it is 25-28 m³/tonnes.
- All types of floors can be combined with a pocket fermenter. A **full floor** ensures the highest biogas production. However, the choice of a particular floor type also has an important impact on business operations. Therefore, there may be several reasons to choose another type of floor as well.
- The most common recurring problems are blockages (by hair, ear tags, etc.). Manure should contain minimum possible amounts of sand, flushing water, antibiotics milk, chemicals and non-pumpable material.

A pocket fermenter of 10 kW produces a net amount of about 60000 kWh per year. It is important that your electricity demand at least approximates this quantity or that it is higher. One of the factors that determines the success of small-scale fermentation is the reversing counter. Because your power meter can turn backwards, it doesn't matter when exactly you consume self-generated electricity. The power grid acts as a kind of temporary battery. However, the system of **reversing counters** is under discussion due to the introduction of the digital meter from 2019. The money you receive when contributing electricity to the net will be considerably lower than when you buy electricity from the net yourself. One option is to store the generated electricity yourself in a battery, but this is not yet profitable at this time (payback period of 19 years according to research done by Inagro (2018)).

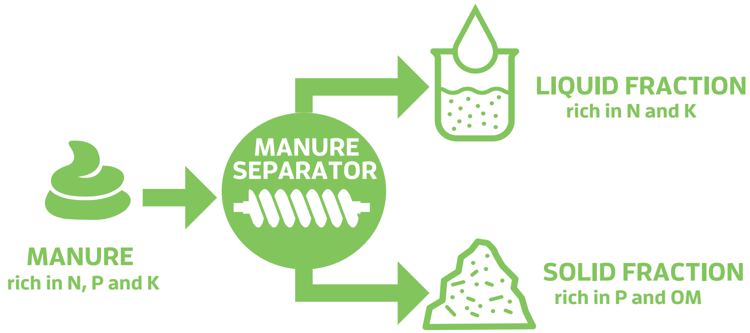
For optimal fermentation, **effective mixing and an external heat source** are needed. In order to increase fermentation yields, energy crops or organic biologic waste can be added, but this is then called co-fermentation and this makes relevant regulation more complex.

In fact, a fermentation plant is comparable to a milk cow because the plant also works with living microorganisms in order to produce energy instead of milk in this case. This also means that the installation cannot be left without necessary **follow-ups**. It is therefore very important to react quickly to possible interruptions. Once the installation is no longer fed and no longer kept at the right temperature, a rapid negative spiral of an ever-decreasing biogas production will occur. The work required as follow up checks for installations varies from farmer to farmer, but it is best to spend at least half an hour per day on this.

ii. Separation

How does it work?

The purpose of separation is to separate raw manure/digestate into a liquid and solid fraction. A characteristic of separation is that the organic material and phosphate accumulate in the solid fraction, and nitrogen and potassium mostly in the liquid fraction. In separation, ± 15% solid fraction and 85% liquid fraction are generally formed. Manure separation in itself does not meet the definition of 'manure processing' but it is an essential step in almost all of the manure processing techniques.



The separation yield is determined by the extent to which phosphate or the dry matter is retained in the solid fraction and varies by type of separator, but also depends heavily on input (type of manure, dry content, age of the manure, extracted from the bottom or the top of the manure pit etc.). The use of excipients, such as flaking agents or organic flocculants, can improve separation efficiency of the centrifuge. However, keep in mind high costs and the potentially negative impact on sales due to reduced availability of P2O5 in the solid fraction.

In the 'Mestbank' declaration, from 2017 onwards, farmers are asked whether or not they have a manure separator. Data from the VLM Mestbank 2017, shows that 127 farmers indicated that they have a manure separator; 71 of these respondents were cattle farmers.

Screw press
An screw press (or screw press filter) is a machine in which a large screw rotates wiliquid a cylindrical trough perforated with 0.1-1 mm holes. The liquid fraction is physically separated from the rest of the manure through these perforations. The screw provides a gradual increase in pressure. Separation is therefore based on particle size.

An screw press is mainly suitable for obtaining a high dry matter content in the solid fraction as opposed to a high shedding of nutrients. This makes the solid fraction suitable for stall bedding. Due to a lower investment cost, high dry matter separation efficiency and suitability for more fibrous manure species, this separation method is mainly applied at cattle farms. An screw press is unsuitable for very liquid types of manure (< 4% DM).

Centrifuge
A centrifuge (also known as a decanter) consists of a closed drum that rotates. Due to centrifugal forces, the heavy, undissolved particles are propelled to the outside of the drum. In the drum, there is a screw that carries these parts away. This separation is therefore based on the specific mass of the particles.

In separation by centrifuge, total-P separation percentage is higher than for DM. A centrifuge is therefore mainly suitable for achieving a high separation of nutrients, potentially by the application of excipients such as flocculants (mostly for digestate). However, centrifuges are more susceptible to sand abrasion than the other types of separators. As a result, maintenance costs will be considerably higher when separating cattle manure. Because of the higher investment and maintenance costs, a centrifuge is less suitable for use in an individual farming business (without external manure supplies), but rather as a primary step in manure processing (e.g. biological processing).

End product characteristics

Both the liquid and the solid fraction are type 2 fertilisers. This means that the spreading regulations are the same as those for raw manure slurry.

Liquid fraction
In the liquid fraction, the **efficacy of nitrogen** (the N uptake compared to that of fertiliser) is **clearly higher** than that of N in slurry. Field trials show that the nitrogen percentage available to plants in the 1st year for ordinary cattle manure is 66%, for the liquid fraction of cattle manure (separation by screw press) it is 71% and for fermented cattle manure it is 75%. Due to the high N/P ratio in the liquid fraction, and also a higher potassium proportion, a saving of almost 40% on fertiliser can be achieved. The liquid fraction after separation can thus increase the yield of grassland.

The **low P-content** ensures that fertilising with liquid fraction is not phosphorus-limiting, so that more livestock manure can be used on Flemish farmland, and the composition of the animal manure (N/P ratio) is better aligned with crop requirements. The high potassium content is also welcome on most sandy soils.

Table 4: Average composition of liquid fraction cattle slurry manure based on databank: 'Bodemkundige Dienst België' (2011-2015) (*EOC = effective organic carbon)

	EOC*	Total N	Mineral N	P_2O_5	K_2O	MgO
Liquid fraction cattle (kg/ton)	10	3.9	2.5	1.0	3.9	1.0

Solid fraction
Solid fraction can contribute to maintaining organic matter content in the soil. The amount of organic carbon that remains in the soil 1 year after administration, and is not yet degraded, is called effective organic carbon (EOC) and contributes to humus fraction and the build-up of organic matter in the soil. The solid fraction of cattle manure (EOC 63 kg/tonne) adds even more organic carbon than cattle stable manure (EOC 47 kg/tonne).

As a stackable manure type, solid fraction can also be stored in various inexpensive ways, such as in a trench silo.

Solid fraction can also be used as a stall box litter as was recently permitted under strict conditions. This is only possible if the manure was produced on the farm itself. Separation must be done by the farmer's own separator. Solid fraction generated by a mobile separator is therefore not allowed. It is also necessary to work hygienically; this means cleaning the separator, hoses and other peripheral facilities after use so that contamination carry-over is reduced to a minimum.

To pass solid fraction on to individual customers, parks and public gardens, it needs to be hygienised first.

Table 5: Average composition of solid fraction of cattle slurry manure based on databank: 'Bodemkundige Dienst België' (2011-2015) (*EOC = effective organic carbon)

	EOC*	Total N	Mineral N	P_2O_5	K_2O	MgO
Solid fraction cattle(kg/tonne)	78	5.8	1.1	2.4	3.3	1.6

Costs

In single farm-scale manure separation, the purchase of an expensive installation (with too much capacity) can be prevented by using a mobile manure separator. The purchase of a single farm manure separator at company level is of no interest for less than 1000 to 2000 tonnes/year.

Table 6: Overview of separator costs[5]

	Centrifuge	Screw press
Flowrate	4 -100 m³/u	4 -25 m³/u
Acquisition	€ 85 000 – 100 000	€ 35 000 – 50 000
Operational costs	1-5 €/tonne	0,5 – 3 €/tonne
Mobile	4 €/m³ (separation) + 4 €/m³ (transport and sales DIF)	20 €/hour (15-20 m³/u) + fixed cost (€ 100) + transport/sales DIF (25 €/tonne) + electricity costs OR 1.8 – 2 euro/tonne cattle slurry (excl. sales dif)

[5] Vannecke, T. et al. (2018) Literature search: 'Waarde van de dikke fractie na mestscheiding als bron van organische stof'. Published by the Flemish Coordination Centre for manure processing; Brugge.

Important points

Differences in the **composition of slurry manure** have a direct effect on the composition of the fractions after separation. The addition of water, such as spill, rinse and cleaning water, lowers dry matter content and thus, separation efficiency. Furthermore, rations, stabling method, storage duration, type of bedding litter in deep bedding boxes, de-mixing or mixing and finally volatility, can all affect the composition of manure.

In addition, separation efficiency also depends on the **age of manure**: the older the manure, the lower the separation efficiency. This is logical given that, in longer storage part of the dry matter is broken down and separation efficiency decreases along with a lower dry matter content.

In the separation process for cattle slurry, the presence of sand should be taken into account. This sand does not or only partly settle in the manure cellar or storage system. This means an increased risk of wear and tear of manure separators. This issue applies to an increased extent when sand is used as bedding in stable boxes.

And finally, make sure you know what you want! A high nutrient separation (centrifuge) will give you a wetter solid fraction, but you can remove more nutrients from your company through the solid fraction. With high DM efficiency (screw press), you will get a dry solid fraction, but more nutrients remain present in the liquid fraction. Discuss with the supplier what specifications the solid and liquid fractions should have for you to continue to process it further.

2. Liquid fraction

i. Biological treatment

How does it work?

The biological process consists of an active-sludge process with nitrification and denitrification. During the nitrification stage, bacteria (in the presence of oxygen, being an aerobic process), convert ammonia (NH_3) to nitrate (NO_3). During the denitrification stage, nitrate (in the absence of oxygen, being an anaerobic process) is in turn converted to the inert and environmentally neutral nitrogen gas (N_2).

The nitrification bacteria that convert ammonia to nitrate, need sufficient oxygen. Oxygen administration is done automatically via aerators. Both normal air and pure oxygen can be administered.

Once the nitrogen from the liquid fraction is transformed into N_2 by micro-organisms, the effluent is stored in the sedimentation tank. This sludge settles and is then stored in a separate tank. Part of the sludge is pumped back to the biology stage in order to maintain the bacterial culture, the remainder can be applied to farmland as animal fertiliser. The effluent (liquid part) is stored in a lagoon and can be used as potassium fertiliser.

The biological method is currently the most commonly used technique in Flanders at 98operationalinstallationsin2017(out of 124 manure processing plants). This represents 13.1 million kg of N or 35% of total nitrogen processing in Flanders, and it is mostly used for porcine manure.
Average capacity is 30 000 tonnes/year to 60 000 tonnes/year (2 tanks). Recently there are also more small-scale installations on the market with a capacity of 6 000 to 8 000 tonnes/year.

End product characteristics

Effluent
The residual final product after biological processing is called 'effluent'. This contains only 10-20% of the phosphorus of raw manure and less than 10% of the nitrogen content. It is often used as potassium fertiliser. It is generally recommended to use effluent at a rate of a maximum of 40-50 tonnes/ha/year. Otherwise, too many salts accumulate in the soil and these can cause damage to salt-sensitive crops.

Table 7: Composition of effluent after biological treatment according to manure guide (Coppens, 2009).

Unit: kg/ tonne	Dry matter	Organic matter	Mineral N	Total N	Mineral N	P_2O_5	K_2O
Effluent	12.5	3	0.5	0.4	0.4	0,4	4.0

Effluent with a low nitrogen content may be applied under certain conditions (according to MAP 5) in periods when other type 3 fertilisers are not allowed to be used. A fertiliser producer can obtain **a permit for fertilisers with a low nitrogen content** for effluent with a total nitrogen content of less than 0.6 kg/tonne. In addition, effluent can be applied **non-emission poor** if the dry matter content is less than 2% and the ammoniacal nitrogen content is less than 1 kg/1000 litres or 1 kg/tonne. In addition, effluent cannot be applied emission poor when dry matter content is less than 2% and ammoniac-nitrogen levels are less than 1 kg/1000 litres or 1 kg/tonne. Effluent can also be used on **derogation plots**. In this case, effluent can only contain a maximum nitrogen level of 1 kg/tonne and a maximum of 1 kg per tonne of P_2O_5.

Further post-treatment of effluent to treated water or dischargeable water is also possible through constructed wetlands for example.

Sludge
Sludge is the result of dissolved solid particle precipitation in sedimentation tanks. Sludge from a manure biology process has an average nitrogen concentration of 2.2 kg N per tonne and a phosphate concentration of 1.4 kg P_2O_5 per tonne (figures from the VLM manure bank). A biology process that also involves a digestate has a higher phosphate concentration. Average potassium content (> 5 kg K2O per tonne) is quite high which makes sludge an interesting animal fertiliser. It not only allows the nitrogen and phosphate needs of crops to be met, but potassium requirements as well, along with supplying organic matter for the soil.

Because **heavy metals** such as copper and zinc from animal manure may concentrate in biological sludge, the maximum dose of these heavy metals according to VLAREMA (1.6 kg copper per hectare per year and 3 kg of zinc per hectares a year) must be taken into account. When maximum permissible yields of these heavy metals in sludge are taken into account according to VLAREMA (800 mg copper per kg dry matter and 1 500 mg of zinc per kg of dry matter), the maximum levels of permitted dosages will not be exceeded at a dosage of up to 40 tonnes of sludge per hectare. If the levels of copper and zinc in the sludge are lower, the sludge can be used at higher doses higher. However, at approximately 50 tonnes of sludge per hectare, phosphate concentration will become limiting.

Costs

Investment costs of a small-scale biological manure processing plant are approximately 460 000 euro. Manure processing costs are approximately 8.70 euro/m³ of slurry or 2.60 euro/kg N being removed. Sales of solid fraction (on average 25 euro/tonne), effluent and sludge are not included in this calculation.

Livestock farmers who have their slurry processed externally pay an average of 17-18 EURO/tonne of slurry, delivered at the gate. So, keep in mind that transport is not included in this price. When effluent is taken back, a reduction of about 4 EURO/tonne slurry can be assigned.

Important points

For proper and constant biological functioning, a **staggered supply of manure throughout the year** is desirable. However, in the fertilising season, there is usually less supply.

The better the sedimentation, the less sludge there will be in the effluent, which is important to sales of effluent with a low nitrogen content. This makes **dimensions of the sedimentation tank** and/or the sedimentation basin most important. Longer storage (9 months instead of 6 months) may be desirable so that sales can remain limited in autumn. Constructors of biological systems also respond to this problem of effluent marketing by developing new types of sedimentation tanks. This means that conical sedimentation tanks are now also being made from concrete, in which sludge is suctioned to the bottom and effluent is at the top.

During the fertilising season, keep a close eye on the **colour of the effluent**. As soon as a substantial amount of sludge is present (the colour will look like 'chocolate milk'), you should take a new sample from the vat and dispose of the product (a mixture of effluent and sludge) as sludge (manure code 934, 'Biological Sludge'), using the values of the new sample.

Sometimes foam can develop and therefore, an **anti-foaming agent** will be needed. However, this is difficult to predict. Also, an **additional carbon source** such as acetic acid, methanol or glycerol may be required, although this is not expected when processing cattle manure.

ii. N-recovery by stripping & scrubbing

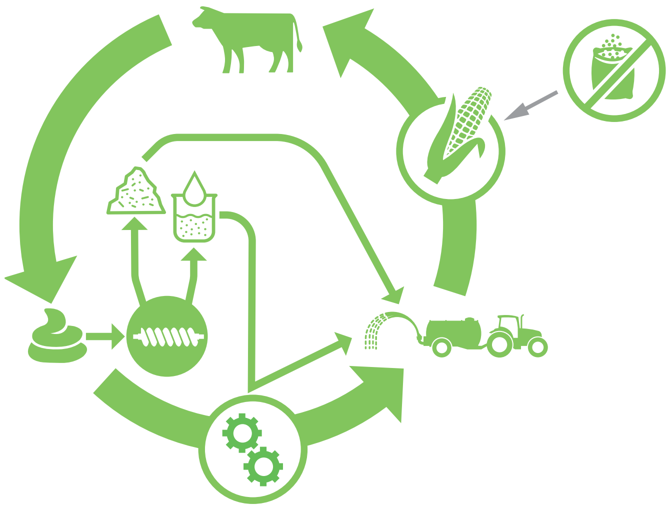
How does it work?

The technique of stripping and scrubbing makes it possible to recover nitrogen from the liquid fraction of cattle manure.

In the first step, the liquid fraction is manipulated to ensure that more nitrogen becomes available in the form of ammoniacal nitrogen (NH_3-N) as only this form of gaseous nitrogen can be recovered. This can be done either by increasing the pH with caustic lime ($Ca(OH)_2$) or by sodium hydroxide (NaOH) to a pH of 10-11 preferably, or by heating the liquid fraction to 70 °C for example. Some constructors also use a CO_2 stripper to remove CO_2. This will already partially increase the pH level.

Next, the liquid fraction is passed over a diffuser or through a stripper tower with a packing material that increases contact surface and where ammonia (NH_3) reaches its maximum gas phase. After this, ammonia is washed from the stripping gas with nitric acid (HNO_3) or sulphuric acid (H_2SO_4) via an air washer system. The result is a liquid nitrogen fertiliser, ammonium nitrate (NH_4NO_3) or ammonium sulphate ($(NH_4)_2SO_4$) respectively. Experiments on a farm Scale (WINGS-pilot in 2018) show that up to 75% of NH_3-N can be removed from liquid fraction of non-fermented cattle manure. This corresponds to 47% of total nitrogen in liquid fraction.

Figure 2: By recovering nitrogen from manure surplus, the nitrogen cycle can be closed and the purchase of fertilisers is reduced.



End product characteristics

Ammonium nitrate
When nitric acid (HNO3) is used, ammonium nitrate (NH4NO3) is produced. This usually contains 15% nitrogen. Ammonium nitrate has been used as a fertiliser since the 1900s and contains both ammonium nitrogen and nitric nitrogen (50/50). Nitrate nitrogen is a very fast-acting substance; ammonium nitrogen is gradually absorbed by plant roots. Although the product has the same characteristics as fertiliser, the status of 'animal fertiliser' currently remains applicable for use on the land according to the provisions of the European Nitrate Directive. Alternative outlets are as a hardener in the production of chipboard and MDF or as an ingredient for fertiliser manufacturers for instance.

Ammonium nitrate can have an explosive character. In practice, pure ammonium nitrate is difficult to detonate. In order to make it more difficult to purchase fertilisers based on ammonium nitrate with a high nitrogen content for the purpose of intentional misuse (explosives), nitrogen content of fertilisers put on the market should not be any higher than 20%.

Table 8: Composition of ammonium nitrate – from the WINGS-pilot (2018)

Parameter	Result
pH	7.43
Total organic C	0.01 %
Total nitrogen	16 % N
Phosphorus	< 0.240 mg/l
Potassium	0.60 mg/l
Chromium, Arsenic, Cadmium, Copper, Lead, Nickel, Zinc, Mercury	Below limits of raw materials declaration
Enterococci and E. coli	< 10/100 ml
Salmonella	absent

Ammonium sulphate
When sulphuric acid (H_2SO_4) is used, ammonium sulphate ($(NH_4)_2SO_4$) is produced. This usually contains 8% nitrogen. Ammonium sulphate is a fertiliser that mainly promotes leaf growth. With regular and prolonged use, it is advisable to closely monitor sulphur concentrations in the soil. An excess of sulphur in the soil impairs crop growth. However, sulphuric acid is cheaper than nitric acid.

Although there is an exception in Flanders to allow scrubbing water (ammonium sulphate) from chemical air scrubbers to be administered as fertiliser (above 170 kg of animal N/ha), this does not apply to ammonium sulphate derived from stripping & scrubbing plants. As for ammonium nitrate, the 'animal fertiliser' Statute remains applicable for use on the land.

Effluent
Effluent is the nutrient-poor residual product that remains after processing. In the stripping & scrubbing plant, ammoniacal nitrogen was removed from the liquid fraction. The organically bonded nitrogen remains in the effluent. Because K also remains present, this effluent will be used as potassium fertiliser on the farmer's own land.

Effluent from a stripping & scrubbing installation is not subject to the same distribution controls as effluent from an organic manure processing plant.

Table 9: Analysis of effluent after stripping & scrubbing WINGS-pilot (2018)

Parameter	Result (kg/tonne)
Dry matter	41
Organic matter	23.0
Total nitrogen	2.8
Mineral nitrogen (amm-N + nitr-N)	1.27
Phosphorus (P_2O_5)	0.38
Potassium (K_2O)	4.0

Costs

According to the WINGS-pilot, manure processing by stripping & scrubbing would cost 21.30 euro/m³ of manure or 10.50 euro to remove 1 kg of nitrogen, excluding removal/processing of solid fraction and effluent. This involved a farm-scale installation with a capacity of 25 m³ of liquid fraction/day and a

dairy farm where no fermentation or other heat source was present. Cattle manure appears to have a buffering effect, which requires more base to increase the pH than other (manure) types. Heating can also mean significant extra costs if no heat source is available on the farm. A third potential cost-increasing factor is that the incoming liquid fraction must be free from fibres to prevent blockage of the filtering gasket material. Effective and thorough separation is therefore essential.

Important points

Since the ratio of NH3-N/Total-N for cattle slurry manure is only 0.5 and for digestate 0.7-0.8, **nitrogen elimination efficiency is higher after fermentation.** In addition, fermentation makes heat available on the farm and a CO2 stripper can be used to increase the pH level. In pig manure, NH3-N levels are also higher.

Incoming liquid fraction should be as **fibre-free** as possible to prevent blockage of the gasket material. Separation by centrifuge seems recommended, but entails high maintenance costs due to sand content in cattle manure. Viscosity or mucosity of cattle manure liquid fraction can also present a problem.

The stripping & scrubbing technique is more complex and more high-tech than other techniques. In addition, the use of nitric acid and sulphuric acid entails related risks. It is therefore important that the **operator or his personnel are adequately trained** in chemical processes and safety procedures.

The stripping & scrubbing technique makes it possible for a farmer to produce his own fertiliser from manure surplus in the long term. This can reduce CO_2-emissions from the dairy farm. Although the ammonium nitrate (15% N) or ammonium sulphate (8% N) that is produced has the same properties as artificial fertilisers, regulations do not currently acknowledge this as such. Both products retain the **status of animal fertiliser**. Adaptation of the definition of 'animal manure' in the European Nitrate Directive is needed to be able to change this situation.

III. Evaporation

How does it work?

When liquid manure flows are evaporated (e.g. effluent after biology), heat is added to the liquid at a certain temperature and pressure. This will evaporate the water and soliden the liquid. Cooling down of the water vapour creates a condensate that can be discharged in some cases. The solidened liquid is still liquid and can be concentrated further by dehydration or drying.

Reducing pressure in the evaporator can reduce boiling temperature so that low-value heat can be used (e.g. from a CHP) or be treated in several steps whereby the vapour of the first step is used as a source of heat for the second step and so on. In every subsequent step, the pressure gets lower, reducing the boiling point after every step, thus resulting in a sufficient temperature difference to transport the heat.

There is a wide choice of available evaporator types. In the context of manure processing, the circulation evaporator, the film evaporator and the spray-film evaporator are used.

End product characteristics

Evaporation of manure slurry produces **manure concentrate**, in which virtually all organic matter and minerals that were in the manure, is concentrated. The maximum dry matter content of manure concentrate obtained by evaporation is relatively low (approximately 25%).

Apart from being and end product, manure concentrate can also be used as a semi-finished product for dehydration.
In addition to concentrate, a water stage also results from manure evaporation. This water stage; the **condensate** from liquid fraction evaporation, will be laden with NH_4 and volatile organic compounds making it unsuitable for discharge into surface water. If evaporation is used on effluent from a well-functioning biology process, volatile NH_3 and organic compounds are converted so that dischargeable effluent is obtained.

Costs

An indication of general costs is not possible because there are multiple factors that determine costs. Investment in an evaporation plant is partly determined by water evaporation capacity, type of evaporator, applied configuration (number of steps, vapour compression), construction material being used related to corrosion, temperature of available heat etc.
Apart from capital charges (interest and depreciation), energy costs are an important part of gross operating costs. By using low-cost residual energy or by recuperating condensation heat, the operating costs of evaporation can therefore be sensibly reduced. Costs range from 2.5 to 50 euros per m^3 of condensate.

Important points

Manure evaporation causes **gaseous emissions** in the form of foul-smelling, non-condensable gases. The levels of odour and ammonia also depend on the nature of pre-treatment and the manure in addition to the evaporation technique being used. A method of air purification is pertinent.

Problems that can arise when manure is evaporated are **changes in composition properties of the manure during evaporation** such as changing levels of viscosity/adhesion, contamination (cleansing with acid and lye) and corrosion of construction material. **Foaming** may also occur, especially at start-up with a water-manure mixture or by carbonic acid that is released when manure is acidified (necessary for nitrogen retention). Choice of anti-foaming agent and design of the acidification plant is of great importance in the latter case.

iv. Phosphorus precipitation

How does it work?

In view of strict fertilisation standards, it is not always the nitrogen content of manure that determines animal manure outlets for the property but rather, the phosphorus content. Recuperation of phosphorus from manure could therefore be an interesting solution for Flemish agriculture.

For the time being, the practice of phosphorus recovery or recuperation is mostly limited to waste water treatment. At present, there is much research (pilot scale phase) into phosphorus recuperation from manure and digestate where the use of chemical acidification and thorough separation precipitates existing phosphorus into phosphorus salts.

This acidification can be done on raw slurry, so that organically bonded phosphorus becomes soluble (soluble phosphate), or with liquid fraction after separation, which already contains the largest proportion of soluble phosphorus. After adding a base to the liquid fraction, phosphorus salts are condensed and can then be extracted from the liquid fraction through filters.

End product characteristics

Phosphorus salts
Precipitation of phosphorus from manure creates a mixture of different phosphorus salts (e.g. struvite). These phosphorus salts are slow-acting P-fertilisers that can be applied in (foreign country) agriculture. Because of the Nitrates Directive limitations, phosphorus salts, produced from livestock manure, are still classified as an animal fertiliser.

P-salts can also be mixed with other fertilisers such as manure compost. This addition causes enrichment of N, P and Mg, which allows a higher price to be put on this mixture.

Costs

No cost data are available for application to fertiliser. Generally, it can be argued that chemical costs are high.

Market prices for phosphorus salts are also uncertain, given their possible impurity. Their value is estimated to be half to two thirds of the price of triple-superphosphate.

Important points

Despite pre-treatment steps, **purity of the end product** is often unsatisfactory.

Phosphorus recuperation is optimal at a pH between 8 and 10. However, a pH value below 9.5 is advisable to avoid **volatility of ammonia** (and its additional odour problems).

Calf manure seems better suited to recover phosphates since this manure is very liquid and about half of the phosphates are present in a soluble form.

A problem that may occur is **scaling** (calcium carbonate deposition), which means that pH control can be disrupted. Regular rinsing with acid may be required. When using steel processing equipment, **corrosion** will be noted.

Varying manure compositions in a flow-through system place high demands on the regulation of chemical dosing.

3. Solid fraction

i. Biothermal drying

How does it work?

In biothermal drying or composting, organic matter is converted and broken down by microorganisms in the presence of oxygen (aerobic process). Bacterial growth in the manure increases the temperature and germ cell death occurs (at > 70 °C, for at least 1 hour). In addition, the organic material stabilizes and reduces in volume and weight by moisture evaporation. In a well-functioning process, the final product will comply with European Regulation Hygiene Standards (VO/1069/2009) and can therefore be exported or applied to parks and gardens.

To achieve hygiene conditions of 1 hour at minimum of 70 °C, poultry manure or other biomass is often added (co-composting) to obtain an optimal C/N ratio (ideally between 25/1 – 35/1 at start-up) and thus achieve the necessary increase in temperature. Oxygen concentration can be maintained by regularly turning the compost (extensive composting) or by aeration (intensive composting). The ideal moisture content for a compost heap is 50-60%.

In Flanders, there are several biothermal drying plants where the process takes place in tunnels that are aerated underneath. There are also composting drums available on the market, in which a rotating drum action ensures aeration. These drums make it possible to hygienise limited amounts of solid fraction on the farm property.

End product characteristics

The composition of the end product depends to a large extent on the incoming flows.

Costs

The price tag will vary depending on the composting technique to be used: In a hall, tunnel composter or drum composter.

For a hygienisation drum, processing costs of about 15 euro/tonne solid fraction are assumed. Depending on the sales outlet, you can to be paid for the manure compost (orders at 4 euros/tonne for sales in France, depending on the season) or you may need to pay extra (or provide extra storage). If you process manure from third parties as well, you can request 'gate fees'.

Important points

The composting process is technically quite simple, but requires **effective follow-ups** or monitoring (temperature, oxygen and moisture content). The quality and maturity of the finished products are often in proportion to the efforts made. So, ensure enough budget for monitoring and analysis!

Whenever any non-proprietary organic materials, such as roadside clippings, natural residues or wood chips are added to manure, an application for a **waste processor permit** must be lodged.

In the composting of cattle manure solid fraction, the **addition of chicken manure** (~ 25%, depending on DM content and C/N ratio) is usually required to achieve the necessary hygiene criteria. The dryer the chicken manure, the smaller the amount that needs to be added. Make sure that you are clear about whether or not there is enough chicken manure available for your business. Other process parameters, for example longer periods at a lower temperature, can also be validated if you can demonstrate that minimum levels of pathogenic microorganism death occur during your composting process.

Check out the possible **marketing channels** or sales opportunities for manure compost in your area and what prices are being paid. Is there any room left for an additional installation? What factors determine the sales prices? Do you have an idea of any possible buyers and have you contacted them yet?

Further **pelletisation**; creating pressed granules from dried manure (possibly with steam) and bagging them may increase sales opportunities, for example for use in gardens, parks and flower beds or for long(er) distance export. It is important for the additional costs of pelletising and bagging (3 to 4 euros/bag of 25 kg) to be justified relative to a potential profitable income.

ii. Thermal drying

How does it work?

In thermal drying, in contrast to biothermal drying, heat is not derived from biological origins, but from an external heat source. The purpose of thermal drying is to reduce the volume and mass of the manure. During drying, germ-count reduction also occurs.

A commonly used drying technique is the tunnel dryer. Manure is placed on a perforated band or floor, through which a fan blows hot air. This dries the product in the tunnel.

Given the need for an external heat source, this technique is most commonly used in combination with fermentation (with CHP).

End product characteristics

Composition of the end product greatly depends on input flows and the technique being used. A dry matter content of 60 to 90% can be achieved.

Costs

An indication of overall costs is not possible because there are multiple factors that determine costs such as: the type of dryer and the desired level of dry matter content etc. Energy costs are a significant part of operating costs. This technique is therefore only useful when a heat source is already present on the property (e.g. fermentation with CHP) or for large scale manure processing initiatives running at a maximum level of energy efficiency.

Important points

Gaseous emissions result from drying manure. Treatment of these gases with an air-cleaner is therefore required.

Problems that may occur when drying manure are composites property changes in the manure during the drying process, such as dry clumps formation, changing viscosity/adhesion properties, contamination (cleansing with acid and lye) and corrosion of equipment construction materials.

Due to the combination of small particles, high organic matter content, high temperatures and low moisture content in dried manure, there is always a **fire or explosion hazard** risk. This is especially so for direct dryers that use hot air for drying.

iii. Liming

Lime treatment of manure aims to sanitise or hygienise and stabilize the manure to a calcareous soil improver. Burnt lime (CaO or agricultural lime) or dolomite (CaMgO) lime is added to dry manure products (solid fraction of pig manure, poultry manure and digestate). This significantly increases pH levels and increases the temperature. Consequently, a proportion of mineral nitrogen is released in the form of ammonia which is then captured in the air purifier in turn.

A significant amount of water is chemically bonded or extruded by evaporation which increases dry matter content.

4. After-treatment to dischargeable water

i. Constructed wetlands

How does it works?

Constructed wetlands or artificial purification/filtration wetlands consist of a connected series of ponds or pools, percolation fields and flow fields, that guide effluent from a biology process for example, by means of currents and pumped flows. Various plant species and substrates are established in the wetlands that each have a specific purification effect. The best-known plant species used for this purpose is reed frass, which often leads to wetlands commonly being referred to as 'reed fields'.

This system has low energy consumption needs, is easy to create and enhances the development of biodiversity. However, large areas are needed to locate these 'reed field' filtration areas.

End product characteristics

Lifespan factors, the types of plants, to harvest or not, the seasons, etc. all determine attainable purification efficiency. As an example, the site at Langemark[6] is discussed. These wetlands form the tertiary purification stage of pig manure after

[6] Michels, E.et al. (2010) 'Constructed wetlands: mestverwerking, landbouw en natuur gaan hand in hand'.

polymer separation and biological treatment and they were brought into use in 2008. Nitrogen concentration of the final effluent is not only consistently lower than the statutory permissible quantity for discharge (15 mg/l), but even complies fully with Basic Environmental Quality Standards (maximum amount of nitrogen 11.3 mg/l). Phosphorus content of the end product is systematically lower than 0.3 mg/l, and therefore well below the legislated discharge standard (of 2 mg/l).

Costs

The cost for wetlands post-processing, including depreciation and monitoring, is around 3.50-€4.50/tonne. In terms of surface area, one hectare of wetland can process 10 000 tonnes of effluent into filtered/purified water per year.

Important points

One important aspect is the necessary **retention time** in this system. This is closely linked to available surface area and thus, it determines maximum capacity.

Reed Grass should be **harvested regularly**, for example after each season of growth. The processing of reeds, for example by composting them for processing into a soil improver, can involve significant costs.

Plant growth and functioning of the microbial system is affected by the **seasons**. It can therefore be difficult to guarantee a constant quality of the final end product, especially in the winter.

ii. Membrane filtration

How does it work?

Filtration involves physical separation while all particles and macro-molecules are retained. The input material for membrane filtration is liquid fraction (of digestate or manure) after separation, or effluent after biological treatment, possibly including pre-treatment (paper filtering, flotation) to prevent membrane contamination. The material is moved through the membrane under pressure.

Depending on pore-size, a distinction is made between **microfiltration** (pores of 0.1 – 5 µm, 0.1-3 bar), **ultrafiltration** (pores of 20 nm – 0.1 µm, 2-10 bar), and reverse osmosis (RO) (0.1-1 nm, 10-100 bar). Microfiltration and ultrafiltration are generally used as a pre-treatment for **reverse osmosis** (with a RO membrane).

Currently, this technique is only used for pig manure and/or digestate.

End product characteristics

Dischargeable water
The water that results can be discharged into surface water or it can be used as process water on the farm itself under specific conditions. Often, an ion exchanger is used after the reverse osmosis stage so that the water end product definitely satisfies all of the conditions required for dischargeability.

Mineral concentrate
The composition of mineral concentrates varies widely depending on the input. On average, N concentration is around 1%.
Nitrogen in mineral concentrates mostly occurs in ammonium form (readily available for plants). Organic nitrogen content is low (only available after mineralisation in the soil). It is therefore important to limit the losses caused by ammonia emissions when using mineral concentrates.

Costs

Research conducted by WUR[7] shows that it costs an average of 7 to 8 euros per tonne of manure to produce a minerals concentrate. This applies to a lifespan duration of 10 years.

On a small scale, this is a relatively expensive technique so that **large-scale installations only are feasible.**

The grade of the mineral concentrate as a fertiliser substitute determines available outlets and thus, the cost price.

Important points

One of the biggest problems with membrane filtration is **contamination of the filter membranes.** Even with good quality business management, filter membrane blockage remains problematic.

According to the Nitrates Directive, mineral concentrates based on processed manure must be applied wiliquid the standards for the use of **animal fertilisers** (i.e. 170 kg N/ha/year).

7 Hoop J.G. de et al. (2011) 'Mineralenconcentraten uit mest. Economische analyse en gebruikerservaringen uit de pilots mestverwerking in 2009 en 2010'.

5. Experimental

i. Fermenting or silage

How does it work?

When using silos or fermentation, solid fraction is stored in anaerobic conditions, in the same way that fodder maize is kept in silos. The ambient temperature is more or less retained during the process, in contrast to composting. The process lasts for 6 to 8 weeks, but the product can even stay ensiled for another two years.

Solid fraction ensiling can be regarded as a controlled storage process; pre-digestion (fermentation), during which limited breakdown occurs. So, this technique is a treatment and does not satisfy the definition of manure processing.

End product characteristics

The study of Viaene (2017) showed that ensiling produced a less stable product; that is, a product with more decomposition of organic matter after application compared to composting of solid fraction and that additional breakdown occurs when opening the silo and on application to the soil. By ensiling, more nitrogen and carbon can be added to the soil per unit of phosphorus (higher N/P and C/P ratio) than by composting.

Costs

Fermentation is an economical **storage technique** that is easy to use. To start with, a mixture of microorganisms is added, namely 2 litres/tonne of fresh organic material. This product costs 1.75 euro/L.

Important points

Fermentation of solid fraction should be seen as a **preservation technique** and is not eligible for a manure processing permit.

ii. Insect breeding

How does it work?

Insects are a valuable protein source for human and animal consumption or they can be bred to produce high quality raw materials such as chitin. As a bio-polymer, chitin provides raw material for various industrial processes or products, including in water purification, the paper industry and livestock nutrition.

Insects can be cultivated on various substrates including manure.

In the M2LARV project: 'Bioconversion of animal manure by protein- and high-fat fly larvae', larvae of the Black Soldier Fly ('Hermetia Illucens') were bred in solid fraction pig manure. In addition, only farm barn air (at approximately 21-23 °C) was used for heating. Active ventilation and agitation of the manure proved to be necessary. After 20 days, the larvae were harvested.

End product characteristics

Larvae
The larvae of the Black Soldier Fly are rich in protein (45-50% on DM basis) and fats (± 20% on DM basis). Their amino acid composition is similar to that of fishmeal. Their fat fraction contains a high level of lauric acid that has an antibiotic effect. The exact composition depends heavily on the diet of the larvae.

Residual substrate
Residual substrate is the product that remains after insect harvest. Research in the context of M2LARV shows that phosphorus content significantly increases in the residual substrate. As a solution to having a phosphorus surplus in a business, processing by using insects does not offer a significantly useful option. High ammonia content explains the high pH, but also makes the substrate phytotoxic (toxic to plants), which sometimes causes inhibition of seed germination. High levels of biological activity are actually left in the substrate. This is why it is useful to put this end product through an additional process first. Composting seems to be the most appropriate approach for this.

Costs

Economic feasibility greatly depends on the value of both the larvae and on the residual substrate and is still uncertain, but profitable cultivation in manure is currently unexpected.

Important points

Cultivation of insects in manure is not easy technically and is still being developed. Only pilot projects have been conducted so far.

Composition and high moisture content of the manure are very important. Moreover, this is a labour-intensive process.

There is currently **no permit** for using manure as a substrate for insect cultivation because insects are covered by 'farm animals' legislation. In addition, it also brings with it the risk of harmful bacteria entering the food chain.

iii. Duckweed

How does it work?

Duckweed is a small, two-leaved plant that reproduces rapidly and contains 30 to 45% protein. This protein is also of high quality because it contains many beneficial amino acids such as lysine and methionine. Duckweed is therefore a promising crop for human nutrition and fodder for pigs, chickens and fish.

As it grows, the small plants absorb nitrogen and phosphorus. By growing them on effluent or liquid fraction manure/digestate, they purify the water, recover nutrients and convert them into valuable proteins.

In outdoor conditions, yields are between 5 and 20 tonnes of dry matter (DM) per hectare per year. In optimal conditions, yields can even reach up to 20 to 55 tonnes per hectare per year.

End product characteristics

The composition of duckweed was investigated during the Ecoferm pilot project in Uddel (The Netherlands). The intention here was to feed the duckweed to calves.

Table10:Composition (g/kgDM)of duckweed compared to fresh grass(source:DeECOFERMKring- loopboerderij in de praktijk'(2016))

Parameter	Duckweed (acc. to ILVO analysis)	Fresh grass
DM	48	163
Raw protein	396	227
Raw ash	164	106
Raw fat	44	44
Raw cell matter	98	228

Costs

The ecological farm 'Ecoferm' in Uddel (The Netherlands), where duckweed was cultivated (in a glasshouse on top of the calf stable) on liquid fraction of digestate and using CO_2 and body heat of the animals, calculated a cost of 1 to 1.50 euro/per kg of DM duckweed. In comparison, the cost price of grass or turnip scraps for example, is 0.15-0.20 euro/per kg DM. This fact, in addition to technical difficulties, caused Ecoferm to stop the production of duckweed. Their yield was 11.5 tonnes per hectare. For a viable business case, yields should be higher by a factor of 5 to 10.

Important points

The use of duckweed as **fodder** is currently **permitted**, provided that certain obligations[8] are met. However, be aware of heavy metals, nitrate accumulation and pathogens that may be present. Duckweed is currently not authorised for use as a nutritional food source for human consumption wiliquid the European Union and therefore cannot be used in the food industry at this stage.

Duckweed cultivation is **not easy**. Duckweed grows best in water with a pH value between 6.5 and 7.5, a temperature between 20 and 30 °C and a conductivity between 200 and 300 µS/cm. When growing on manure products, nutrient content was often too high, which caused the small plants to perish.
Water birds are also crazy about duckweed. In open air cultivation,

[8] Compeer A.E. (2017) 'Rapport Blauwe keten: Eendenkroos richting veevoer'.

both consumption damage and the **wind** can pose a problem. In addition, **round ponds/pools** should be chosen to avoid dead corners without current flows.
The harvest of Duckweed is an **intensive and time-consuming** process. If you want to use it as fodder, it is best to dry it first; the plant consists of 90% water. **Drying** (for 30 hours at 40 °C to 90% DM) decreases the volume (lower transport costs), prolongs lifespan storage time, and animals will feel satiated or full less quickly.

Part III:
Rules of the game

The practice of manure treatment and processing is covered by a number of different legislations at various administrative levels. It is not easy to find your way through this tangled web of legislation. In addition, beginners are confronted by all sorts of choices and questions: how do I position the installation in the environment, what administrative obligations do I need to meet, am I entitled to any subsidies...?

This manual provides a guide to the various facets that you need to take into account for your manure processing project. Please note that not every legislation applies to every technique and/or end product. Employ a consultant to guide you along with your project.

I. Let's do this!

You have decided on the technique in which you want to invest to process or treat the manure on your farm. What next?

Do you have the necessary funding available?

In Flanders, various means of support are available for farmers:

VLIF-investment support
Only farmers can benefit from VLIF investment support. A manure separator can attract up to 30% of support, for the potentially associated mixer and pipes: 15%. For peripheral equipment and peripheral infrastructure for pocket fermentation plants, investment support of 30% also applies. For more information, see:
https://lv.vlaanderen.be/nl/subsidies/vlif-steun-voor-de-land-en-tuinbouw

VLIF-project support for innovations in agriculture
This project support stimulates pure innovation and renewal in the agricultural and horticultural business industry and complements standard VLIF investment support. Investments that are not yet available on the VLIF list of eligible investments, may nevertheless attract a subsidy. An application must be lodged during current application periods. For more information, see:
https://lv.vlaanderen.be/nl/subsidies/vlif-steun/projectsteun-voor-innovaties-de-landbouw-0

Further support measures for pocket fermentation
Starting from 1 January 2018, starting small-scale biogas plants will no longer receive support through green biogas permits and co-generation licences. These have been replaced by a one-time investment subsidy. Existing installations retain their licenced status. For more information see:
https://www.biogas-e.be/kenniseninnovatie/investeringssteun

Development and research projects
On a regular basis, calls are made for various projects and specific funding programmes for which applications can be lodged. Contact VCM to find out if there are any current subsidy opportunities for manure processing projects.

An application for an environmental permit must be lodged for your project.

The environmental permit replaces and combines the urban planning permit and the milieu permit. Depending on your chosen technique, a simplified procedure or normal procedure will apply.

Permit for mobile separator?
All farmers wishing to make use of a mobile separator must adhere to the relevant environmental permit legislations (VLAREM). Small-scale installations, mobile or located on a livestock farm, can be classified under heading 9 (instead of heading 28.3). Such installations belong to the running of the livestock farm business. Prerequisite conditions for this are that only livestock manure produced at that specific location may be processed or treated in the installation, without any mixing of waste. Adaptation of the authorisation can be facilitated by a simplified procedure.

Intake of manure from third parties and/or green waste from outside of the business?
If manure from third parties and/or green waste is accepted onto the property for processing in an installation, a permit must be requested under the heading of 28.3 (manure processing) and/or 2.2.3 (storage and biological treatment of waste).

2. Ready; let's go...

Has the environmental permit been approved? If so, construction and/or installation of the manure processing installation can begin.
Before the installation starts operating, ensure that you have the following matters organised:

Application for acknowledgement of installation in the context of EU 1069-recognition

A processing plant that processes manure from third parties must have 'light 1069 recognition' status to be able to store unprocessed manure on the property.

If you have chosen an installation for the purpose of delivering hygienised manure products (for example for export or marketing to private individuals), this installation should be granted 'full 1069 recognition'. The formal authority for this is the 'Mestbank'.

For full-1069 recognition status, it is necessary to comply with prescribed hygiene conditions, which is treatment of manure products at 70 °C for 1 hour. Alternative treatments may also be recognized (e.g. a lower temperature for longer periods of time). This alternative treatment must first be validated (this is currently only possible by the 'Elsinga' company from the Netherlands).

Make your choice for mass and nutrient flows monitoring in manure processing

All animal manure that is transported to or from the manure processing plant must be weighed. Transports for manure exports must also be weighed. You can choose from 2 options:

- Standard: weigh-bridge or flowmeter, supported by weighing vouchers, or start and end flowmeter readings;
- The mass protocol: annual reporting of mass flows via the approved protocol.

3. Plant operation

Comply with all of the (administrative) obligations regarding installation operations.

- **Identification with the 'VLM-Mestbank' authority**

If manure from third parties is being processed, the farmer must identify/register as a treatment/processing business at the Manure Bank (become listed in the 'Mestbank' records).

- **Weigh all input and output.**

- **(Temporary) storage of solid fraction needs to be done without any risk of manure seeping into any waterways.**

- **A mobile separator must be cleaned thoroughly before it is used with a subsequent installation (for hygienic/sanitary reasons).**

- **Meet all necessary licencing obligations.**

Comply with all administrative obligations related to input and output.

- **'Mestbank' reporting**

As a farmer, you must record all manure processing activities you undertake on your farming property, using the 'Mestbank' declaration forms.

- **Analysis of end products**

Analyses must be undertaken for all end products of manure processing. These are to be done by an accredited laboratory. Analysis results are valid for 3 months.
Given that the composition of solid and liquid fraction depends on separator efficiency, no basic values apply, and actual composition (nitrogen and phosphate) must always be determined based on the analysis.

- **Treatment capacity > 300 kg P_2O_5/year?**

Compulsory ongoing record keeping of supplies and disposals of separated manure products is required.

Compliance with all of the administrative obligations related to distribution of end products

Obviously, suitable outlets must be explored for the different end products of a manure treatment/processing plant. These can be present wiliquid Flanders, on Flemish farmland as well as on non-agricultural land such as gardens, parks and flower gardens, or outside of Flanders. Be proactive in checking what sales/distribution outlets are available for your products!

In order to meet manure processing obligations (to obtain a manure processing permit (MVCs)), the end products of manure processing must be exported outside of Flanders or applied to non-agricultural land wiliquid Flanders. For those end products that are covered by the 'Fertiliser' Statute, and applied to Flemish farmland, MVCs can also be obtained.

Depending on the type of product, different administrative obligations must be met.

Non-hygienised products to be distributed wiliquid Flanders (farmland)

- **Transport documents**

Transport of solid fraction or liquid fraction after separation is always done by an accredited manure manager, using the 'MestAfzetDocument' or MAD records system (manure distribution documentation).

Transport of effluent produced at a processing unit located in a particular municipality to an operation located in the same municipality or an adjacent municipality, and the transfer of effluent from intermediate storage at an animal manure producer's property to the users, can be controlled via 'neighbourhood' regulations.

- **Licence to apply manure products on Flemish farmland**

Liquid fraction of pig manure with a liquid fraction permit may be applied to derogation farm land as derogation manure. Effluent with formal effluent permits can also be applied to derogation land plots (at ≤ 15 tonnes/ha). This effluent may contain maximum levels of 1 kg N/tonne and a max. of 1 kg/ tonne of P_2O_5 and must not be mixed with animal manure, other fertiliser matter or artificial fertilisers. For effluents containing a low level of ammoniacal nitrogen (N < 1 kg NH_4-N/1 000 litres), emission-poor dosing is not compulsory.

In addition, effluent with a permit for 'fertilisers with a low nitrogen content' may be applied under certain conditions in periods when type 3 fertilisers without certification must not be applied. The prerequisite is that this substance contains less than 0.6 kg N/tonne, with a maximum fertilisation level of 30 kg N/ha, of which 10 kg is mineral N.

All of these exceptions require formal authorisation (permits) to be obtained from the 'Mestbank' .

Hygienised products for distribution wiliquid Flanders (Flemish farmland or non-agricultural land)

Transport documents

Transport of animal manure products is generally done through an accredited manure hauler and using the 'MestAfzetDocument' (MAD) record system. For distribution of the hygienised end products of manure processing, in certain cases, the principle of 'authorised distributor' can be used. Transport can therefore be carried out by an un-accredited manure hauler, along with a shipping document. In this situation, the manure processor himself acts as the contact person for the 'Mestbank'.

If you want to sell hygienised manure products to gardens, parks and landscaped areas without the need for distribution documents, records of this process must be kept in a separate 'register for small manure transports'. This can only be done for such products for transport loading capacities from 500 kg to 3 500 kg or for transporting products that are packed at a maximum weight of 50 kg per item.

FOD-exemption

Trading of end products of manure processing is regulated at federal level through the Royal Decree of 28 January 2013. Given that end products of fermentation (digestate) and manure processing are not listed in this legislation, an exemption should be sought for these products from the Public Health Department; Food and Environmental Safety section. This exemption is valid for a maximum of 5 years and costs 1 500 euros.

FAVV-recognition

To trade in fertilisers/soil improvers, companies must have formal FASFC approval. Annual inspection visits are carried out by FASFC inspectors. Checklist are audited (reporting duties, traceability, infrastructure, equipment, hygiene, packaging and labelling and auto- checks).

Hygienised products for distribution beyond Flanders

FOD-exemption

The Royal Decree for fertiliser trade only applies the trading of end products of manure processing wiliquid Belgium (including private distribution). For export, FOD-exemption is therefore strictly speaking not applicable. However, some countries of destination or certain customers do request this recognition status as fertiliser in the country of origin, which will then require compliance with this KB after all.

FAVV-recognition

See above.

Transport documents

For the distribution of hygienised end products of manure processing, and in certain cases, the principle of 'authorised distributor' can be used. Transport can therefore be carried out by an un-accredited manure hauler, along with a shipping document. In this case, the manure processor himself acts as the contact person for the 'Mestbank'.

For transport outside of Flanders, a commercial trading document must also be present in addition to manure distribution documents/shipping documentation. This can be obtained by application at the 'Mestbank'.

Compliance with legal requirements of the country of destination (different countries have different regulations)

For distribution of manure products to France and Germany, the VCM has created an overview of all relevant legal obligations. You can find this information on the VCM website by clicking on 'Bibliotheek < Wetgeving afzet van eindproducten'.

End products with similar properties to fertiliser

Certain end products from manure processing, such as ammonium nitrate, ammonium sulphate, struvite and mineral concentrates, have the same properties as fertiliser. However, because these products were basically produced from manure, they retain 'animal manure' status and the standard of 170 kg N from animal manure/ha still applies. The application of fertilisers to land is governed by the **European Nitrate Guidelines**.

European Fertiliser Regulations control fertiliser trading wiliquid Europe.

In situations where flows other than animal manure are processed in the installation.

Besides being an installation for the co-processing of waste matter, a manure treatment and processing plant is also a treatment plant for waste processing. The final products produced by these installations are therefore waste products. Given that a number of conditions are achieved, waste matter can be recognised as raw material, which allows it to be used as fertiliser or soil improver on Flemish farmland. For this purpose, a 'raw material declaration' can be requested via the OVAM Website.

As soon as organic-biological waste is used in a biological process (e.g. composting/fermentation) for the production of fertilisers or soil improvers, a formal permit for inspection for these finished products (e.g. compost or digestate) is required. This qualification provides additional guarantees to the customer about the product itself, as well as about the production process.

TIPS:

Many different legislations are being maintained by various official bodies. This is done administratively, but also on site (by announced and unannounced visits). Therefore, always try to be prepared for a possible audit and keep all of your documents in orderly filing systems. If samples are taken, and the analytical result does not seem to be correct, you have the right (at your own expense) to take a control sample yourself for testing at an accredited laboratory.
Try to establish a protocol with fixed data, procedures and people responsible for this legal administration process. You may also want to consider outsourcing this responsibility to someone else.
The VCM website **(www.vcm-mestverwerking.be)** provides more information about relevant legislations. You can also refer to them for first line advice.

Part IV:
Project WINGS

This manual was created wiliquid the WINGS project. The WINGS project is a collaborative between VCM and Danone, with support from the Danone Ecosystem Fund. In addition, a pilot group of dairy farmers also provide advice and guidance to the project from a practical perspective.

The aim of the project is to investigate solutions for manure surplus on dairy farms. WINGS wants to achieve more sustainable manure processing with nutrient recovery. This is why testing was done with a stripping and scrubbing installation on a Meerhout dairy farm. Results of this test proved to be very valuable and confirmed that it is possible to recover nitrogen from non-fermented cattle manure. Unfortunately, at that time, the business case for this stripping and scrubbing installation was not viable and distribution of end products was undefined due to limitations imposed by current legislations.

In addition to nitrogen recovery from liquid fraction, the project also investigated options for increasing the value of solid fraction. Solid fraction of cattle manure is an interesting source of organic matter. The effective organic carbon content (EOC) (being the amount of carbon that remains in the soil I year after administration and thus contributes to the accumulation of organic matter in the soil) in solid fraction cattle manure is as much as 34% higher than that in cattle stable manure. This is why the LEADER Haspengouw project: 'solid fraction to boost organic matter' was also launched as part of the WINGS project; a VCM project, Soil Science Service of Belgium, PIBO Campus, PVL, Farmer's Association (Boerenbond) and Danone, supported by the European Agricultural Fund for Agricultural Development (EAFRD), the Flemish Government and the Province of Limburg. This project aims to stimulate farming businesses of Haspengouw to use solider fraction instead of fertiliser in order to maintain the carbon content of their farming plots in this way. Similarly, in collaboration with pcfruit, a field trial was initiated to investigate the use of solid fraction in fruit cultivation, specifically for pears. Outcomes of this trial were not yet available at the time of publication of this manual.

Besides manure surplus, the WINGS project also addresses emissions on dairy farms. All Danone dairy farmers were given the opportunity to have free CO_2– and energy testing done by the innovation support site. Together, the 32 tested dairy farms can save 131 300 kgs of CO_2 by applying energy-saving measures and implementing (partial) conversion to renewable energy. Major actions were explored over 3 study days in 2018. Secondly, 4 dairy farmers are experimenting with the Dutch Recycling-approach which sets out to map nutrient losses (N, P and C). Results are expected in early 2019.

Consumer demand for more sustainable dairy farming continues to gain voice. The WINGS project has attempted to contribute to the evolution towards a more circular/recycling agricultural system, with fewer emissions and more sustainable manure processing. However, it will not stop here. By working together, we will generate even more impact and we can increasingly put a circular economy on the agenda. We would like to thank all parties for partnering with us and for providing us with support for this project!

This manual bundles possible solutions for the manure surplus in dairy farming. The brochure starts with a reflection exercise to determine the lines for the manure processing project. Questions such as "Which scale size is realistic for you business?" or "who is going to run the installation?" are discussed. Then an overview is given of the techniques that can be applied to cattle manure. Both traditional manure processing techniques and more innovative solutions are discussed. Finally, a concise overview is given of the subsidy possibilities and the applicable legislation.

This brochure is a collaboration of:

vcm
Vlaams Coördinatiecentrum Mestverwerking

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