Additional prerequisites for fertiliser management

Consequences for the use of recycling-derived fertilisers

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Summary and conclusions

The objective of the NWE-Interreg project ReNu2Farm is to increase the use and production of recycled nitrogen (N), phosphorus (P) and potassium (K) for fertilizers in Northwest Europe (NWE). The proper development of the market for biobased, recycling-derived fertilisers (RDF's) is hampered among others by the legal status of the fertilisers. Because the products are often produced from waste or from animal by-products (e.g. sewage sludge, food waste and animal manure), the end products are considered as waste or animal by-products as well. For that reason, it is not allowed or difficult to trade these products between member states within EU as fertiliser. In two other reports that have been produced within the scope of ReNu2Farm, the legislative framework at EU and national level for the trade and use of RDF's has been described. In addition to the consequences of the legal status of fertiliser products for the possibilities for the trade and use of the products as fertiliser, the legislation for the application limits is also of relevance for the potential use of recycling-derived fertilisers (RDF's). That is the reason that we describe the legislation for the application limits at European and national level and the consequences for the use and application of RDF's in this report.

For the use of recycling-derived fertilisers (RDF's) application limits for animal manure and other organic and mineral fertilisers are of relevance. Within the scope of the Nitrate directive most countries in NW Europe have formulated application standards for animal manure (170 kg total N per ha and 230-250 kg total N per ha for grassland on dairy farms in some countries), but there are differences in the way countries have implemented additional application standards in their national legislations. Some countries have formulated application standards for the summed application of N with animal manure ánd other fertilisers, which are sometimes based on total N (which is the case for UK, Ireland, France and Belgium / Flanders (optional)) and sometimes on effective N (which is the case for Belgium / Flanders (optional) and the Netherlands). Germany is using the N balance in the legislation with respect to the allowed N application, and has formulated maximum amounts for the allowed N surplus. In addition, some countries have formulated application standards for phosphate (e.g. Belgium / Flanders and the Netherlands).

Next to the application limits, countries have also formulated the allowed application periods for various fertilising products. These periods vary between countries, regions, soil types, crop types and fertiliser types. When using RDF's, the application standards for animal manure and/or for the summed N input with animal manures and other fertilisers and additional regulations for application periods and/or prescribed ways of storage and application (e.g. ammonia emission should be prevented during storage and application of animal manure and Renure products) should be respected.

The main conclusions per fertiliser type are as follows:

For composts it is of importance whether they are produced from animal manure or from other sources, like green waste or household waste. Composts produced from animal manure have the legal status of animal manure and for that reason the application standard of 170 kg total N per ha is of relevance for that product. That is not the case for composts produced from green waste and household waste. As of 16 July 2022, some of the composts could be used as a component for the production of EU fertilisers with CE marking. In some countries (e.g. Flanders and the Netherlands) the *effective* N applied with compost should be taken into account for the N application standard, while in other countries (e.g. France, UK and Ireland) the *total* N applied with compost should be taken into account.

Ashes from the incineration or gasification of biowaste, sewage or manure are considered waste and can only be used as a fertiliser if authorised as such. Germany and the UK have a limited authorisation of ashes as a fertiliser whereas Flanders and France have given derogations for the ashes from specific producers. As of 16 July 2022, some of the ashes could be used as a component for the production of EU fertilisers with CE marking. The Nitrate Directive does not pose any restrictions on the use of ashes as a fertiliser. Ashes are mostly used as a PK-fertiliser and/or for their neutralising value. In countries where the ashes are authorised ánd where application standards for phosphate are in place (e.g. in Flanders), the allowed doses of ashes are limited by the P application standards.

Struvite derived from sludge treatment (sewage or biowaste) is a biowaste and can only be used as a fertiliser if authorised as such. This is of relevance for the struvites considered in this project. Only Germany and the Netherlands have a limited authorisation of struvite as a fertiliser whereas Flanders and the UK have given derogations for the struvite from specific producers. As of 16 July 2022, some of the struvites could be used as a component for the production of EU fertilisers with CE marking. The fertiliser application is generally limited by application standards for total P and N (total or effective).

Ammonium sulphate and ammonium nitrate can be produced directly from liquid animal manure through a stripping-scrubbing process. Following the strict interpretation of livestock manure in the Nitrate directive, the ammonium sulphate would be considered a manure product, and the application limit of 170 kg N per hectare applies. However, for the use of ammonium salts as a component for EU fertilisers with CE marketing, the ammonium sulphate is regarded as a waste product that does not fall under the scope of the Animal by-product regulations. Countries seem to differ in the definition of the ammonium salt products, with some countries (Belgium, the Netherlands) following the definition of the Nitrate directive, while other countries follow the definition of the Fertilising product regulation. This will also impact the transport and handling of the

product as either an ABP or a product. In dependence of the composition in relationship with the criteria for SafeManure, the ammonium sulphate could get the Renure status. In that case, the same provisions apply to the ammonium sulphate as to N containing chemical fertilisers and it can be applied on top of the application limit of 170 kg N per hectare. However, because the S content in ammonium sulphate is relatively high in comparison with N, high N doses with ammonium sulphate are not possible within the limits of the Good Agricultural Practices. Because the ammonium nitrate does not contain S, it can be applied in larger amounts than the ammonium sulphate.

1 Introduction

The objective of the NWE-Interreg project ReNu2Farm is to increase the use and production of recycled nitrogen (N), phosphorus (P) and potassium (K) for fertilizers in Northwest Europe (NWE).

Within the scope of sustainable agriculture and a circular, biobased economy, it is crucial to find ways to reduce quantities of non-recycled nutrients like N, P and K and to decrease the dependency on nutrient import. In the NWE Interreg project ReNu2Farm opportunities for the replacement of nutrients from traditional mineral fertilisers by recycling-derived fertilisers are explored. Within the NWE territory, regional differences can be identified with respect to nutrient supply and demand. Hot spots with a surplus of N and P from animal manure are identified in the NWE territory and compared to regions with a shortage of nutrients from animal manure. Opportunities for the replacement of nutrients from traditional mineral fertilizers by recycled fertilizers from regions with a nutrient surplus are explored within the scope of the current project.

The proper development of the market for biobased, recycling-derived fertilisers (RDF's) is hampered among others by the legal status of the fertilisers. Because the products are often produced from waste or from animal by-products (e.g. sewage sludge, food waste and animal manure), the end products are considered as waste or animal by-products as well. For that reason, it is not allowed or difficult to trade these products between member states within EU as fertiliser.

In another report that has been written within the scope of the ReNu2Farm project (Van Schöll & Postma 2022-I) the legislative framework at EU level for the trade and use of recycling-derived fertilisers has been described. An important development was the adoption of the EU Fertiliser Product Regulation 2019/1009 in June 2019, which aims at 'facilitating the recognition of organic and waste-based fertilisers in the single market and thus encourage the recycling of bio-nutrients as fertilising products in the circular economy'. When strict rules for the safe recovery of nutrients into secondary raw materials are fulfilled, those raw materials may be used as a component of CE-marked fertilising products, which are classified in Product Function Categories (PFC's). The consequence is that RDF's may become an EU fertiliser product, provided that they meet the requirements for raw materials (classified in component material categories, or CMC's), production and contaminants.

EU Regulation 2019/1009 is facultative, which means that it exists next to the continuing national legislations for the trade of fertilisers. National legislations and regulations are

especially of interest for products that are meant for use in the region or country where they are produced and/or for products that are exported from one country to another.

In a second report, national legislations for the trade and use of fertiliser products in countries in North West Europe (NWE) are described (Van Schöll & Postma, 2022-II). With respect to the consequences of national legislations for the possibilities for recycling-derived fertilisers (RDF's), we concluded that

i) RDF's are treated differently in the national legislations of member states within NW Europe,
ii) a specific RDF may have a fertiliser status in one country and a waste status in another country,
iii) mutual recognition is interpreted differently by the member countries within NW Europe and
iv) it requires a lot of administrative work and good knowledge of the authorisation procedures for getting a fertiliser or end-of-waste status in the various EU countries.
v) the differences in national legislations between countries are undesirable and hampers the creation of a level playing field.
vi) the implementation of the regulation EU/2019/1009 on fertilising products is a breakthrough for the recognition of recycling-derived fertiliser products.

In addition to the consequences of the legal status of fertiliser products for the possibilities for the trade and use of the products as fertiliser, the legislation for the application limits is also of relevance for the potential use of recycling-derived fertilisers (RDF's). That is the reason that we describe the legislation for the application limits at European and national level and the consequences for the use and application of RDF's in this report.

2 EU legislation on use of fertilisers

2.1 Introduction

At the European level there is no legislation directly aiming to regulate the application of fertilisers. There is however legislation aiming to protect the quality of the ground and surface waters throughout the European Union that strongly impacts the application of fertilisers. Most relevant are the Water Framework directive and the Nitrate directive.

This legislation sets goals and targets for the chemical and ecological status of surface and ground water and quality standards. Nitrogen and phosphorus are amongst the elements that strongly affect the chemical and ecological status of waters. Regulation of the flow of nitrogen and phosphorus from agricultural areas to ground and surface water is therefore seen as key issue. This can be achieved by measures on the application of fertilisers and manures.

2.2 Water Framework Directive (WFD 2008/98/EC)

The Water Framework Directive (WFD 2008/98/EC) aims to establish a framework for the protection of all waters including rivers, lakes, estuaries, coastal waters and groundwater, and their dependent wildlife/habitats under one piece of environmental legislation. It sets out rules to halt deterioration in the status of European Union (EU) water bodies and achieve 'good status' for Europe's rivers, lakes and groundwater. (Source: https://eur-lex.europa.eu/browse/summaries.html).

Specifically the WFD aims to:

- protect/enhance all waters (surface, ground and coastal waters)
- achieve "good status" for all waters
- restoring the ecosystems in and around these bodies of water;
- reducing pollution in water bodies;
- manage water bodies based on river basins or catchments
- guaranteeing sustainable water usage by individuals and businesses.
- involve the public.

The Water Framework Directive is linked to a number of other EU directives, (https://www.epa.ie/water/watmg/wfd/), illustrated in Figure 2 1. These include Directives relating to the protection of biodiversity (Birds and Habitats Directives), directives related to specific uses of waters (drinking water, bathing waters and urban wastewater directives) and to directives concerned with the regulation of activities undertaken in the environment (Industrial Emissions and Environmental Impact Assessment directives. Directives on topics such as Floods and the Marine Strategy Framework have significant

linkages with the WFD which is also supplemented by the Priority Substances Directive and the Groundwater Directive. The Sustainable Use of Pesticides and the Sewage Sludge Directives provide for the control of materials applied to land. The Nitrates Directive forms an integral part of the Water Framework Directive and is one of the key instruments in the protection of waters against agricultural pressures.

Figure 1 WFD Interaction with other EU Legislation (Source: SWMI, 2015 on https://www.epa.ie/water/watmg/wfd/)

The WFD places clear responsibilities on national authorities of the member states (Source: https://eur-lex.europa.eu/browse/summaries.html). They have to:

- identify the individual river basins on their territory — that is, the surrounding land areas that drain into particular river systems;
- designate authorities to manage these basins in line with the EU rules;
- analyse the features of each river basin, including the impact of human activity and an economic assessment of water use;
- monitor the status of the water in each basin;
- register protected areas, such as those used for drinking water, which require special attention;

- produce and implement 'river-basin management plans' to prevent deterioration of surface water, protect and enhance groundwater and preserve protected areas;
- ensure the cost of water services is recovered so that the resources are used efficiently and polluters pay;
- provide public information and consultation on their river-basin management plans.

The approach to protect and improve the quality of water differs between surface waters and groundwater (Source: https://ec.europa.eu/environment/water/water-framework/info/intro_en.htm).

For **surface water**, both the ecological and chemical quality have to be protected and improved. Good ecological status is defined in terms of the quality of the biological community, the hydrological characteristics and the chemical characteristics. As no absolute standards for biological quality can be set which apply across the Community, because of ecological variability, the controls are specified as allowing only a slight departure from the biological community which would be expected in conditions of minimal anthropogenic impact.

Good chemical status is defined in terms of compliance with all the quality standards established for chemical substances at European level. These include standards for nitrogen and phosphorus.

For **groundwater** the presumption has been that it should not be polluted at all. For this reason, setting chemical quality standards may not be the best approach, as it gives the impression of an allowed level of pollution to which Member States can fill up. Few such standards have been established at European level for particular issues (nitrates, pesticides and biocides), and these must always be adhered to. But for general protection, the approach comprises a prohibition on direct discharges to groundwater, and (to cover indirect discharges) a requirement to monitor groundwater bodies so as to detect changes in chemical composition, and to reverse any anthropogenically induced upward pollution trend.

Agriculture is a substantial source of N and P in surface and ground water. Therefore, the 'river-basin management plans' need to include measures to reduce the flow of nitrogen and phosphorus from agriculture, i.e. by controlling the fertiliser application. In addition, the Nitrate Directive specifically aims to reduce the flow of nitrates from agricultural sources.

2.3 Nitrate directive (91/676/EEC)

The Nitrates Directive (Council Directive 91/676/EEC) aims to protect water quality across Europe by preventing nitrates from agricultural sources polluting ground and surface waters and by promoting the use of good farming practices. Farming is responsible for

over 50 % of total nitrogen discharges into surface waters. The Nitrates Directive forms an integral part of the Water Framework Directive and is one of the key instruments in the protection of waters against agricultural pressures. (Source https://eur-lex.europa.eu/browse/summaries.html).

Implementation measures of the Nitrates Directive that countries have to take are ((https://ec.europa.eu/environment/water/water-nitrates/index_en.html)):

- designate as vulnerable zones all those draining into waters which are or could be affected by high nitrate levels and eutrophication, the so-called nitrate vulnerable zones (NVZ's)
- draw up a code of Good Agricultural Practices. Codes should include:
    - measures limiting the periods when nitrogen fertilizers can be applied on land in order to target application to periods when crops require nitrogen and prevent nutrient losses to waters;
    - measures limiting the conditions for fertilizer application (on steeply sloping ground, frozen or snow covered ground, near water courses, etc.) to prevent nitrate losses from leaching and run-off;
    - requirement for a minimum storage capacity for livestock manure; and
    - crop rotations, soil winter cover, and catch crops to prevent nitrate leaching and run-off during wet seasons
- establish action programmes for the NVZ areas to reduce nitrate pollution of waters; taking into account available scientific and technical data and overall environmental conditions. These programmes must include:
    - measures already included in Codes of Good Agricultural Practice, which become mandatory in NVZs; and
    - other measures, such as limitation of fertilizer application (mineral and organic), taking into account crop needs, all nitrogen inputs and soil nitrogen supply, maximum amount of livestock manure to be applied (corresponding to 170 kg nitrogen /hectare/year).
- limits the application of nitrogen from manure: in areas covered by Action Programmes, the Directive prescribes that the highest amount of nitrogen from manure that can be applied annually is 170 kg/ha
- monitor the effectiveness of the action programmes;
- provide training and information for farmers, where appropriate.
- carry out a comprehensive monitoring programme and submit every 4 years, a comprehensive report on the implementation of the Directive. The report includes information on nitrate-vulnerable zones, results of water monitoring, and a summary of the relevant aspects of codes of good agricultural practices and action programmes.

Figure 2 Nitrates vulnerable zones. Countries in blue have designated the whole territory as NVZ (art.3.5) (https://water.jrc.ec.europa.eu/ 01/09/2020)

All member states have implemented the mandatory action programmes, taking into account the specific pedo-ecological conditions in their territory. All action programmes use the maximum limit of 170 kg nitrogen (total N) per hectare per year in NVZ for the application of animal manure. In some countries, all agricultural land is declared as NVZ (f.i. in the Netherlands, Germany), other member states have designated specified areas as NVZ (e.g. France) (Figure 2 2).

Higher applications of animal manure than the 170 kg N per hectare are allowed in certain situations, provided that nitrate concentrations in groundwater will not exceed 50 mg per litre, e.g. because of high N uptake by crops. These exceptions are called 'derogations', which have been granted to the Netherlands, Belgium (only in Flanders), Ireland and UK (Northern Ireland, England, Scotland and Wales) and Italy (regions of Lombardia and Piemonte) (https://ec.europa.eu/environment/water/water-nitrates/index_en.html). Germany had a derogation until 2013, but has lost it in 2014 (Van Gruisen, 2017).

Chemical fertilisers are not bound to the limit of 170 kg N/ha, but should be used in accordance with Good Agricultural Practice. Application rates may be higher provided that the fertilisation standards of Good Agricultural Practices are met and groundwater and surface water are not polluted by nitrates. In some EU countries, application limits for N take into account N fertiliser replacement values (NFRV's) of organic fertilisers, because not all N is available for crop uptake and will cause a risk for NO3 leaching. This is for example the case in the Netherlands and Denmark (Van Dijk & Ten Berge, 2009), where the N application limits are based on effective N. However, in other countries, like Belgium (Flanders) and France, the legislation is based on the total N application. This will be described more extensively in the next chapter.

In addition to maximum application limits, the action programmes also include application measures to increase the effectiveness of the fertilisers and limit emissions, such as timing of application (e.g. applying manure outside the growing season is not allowed) and application modes (e.g. insert animal manures into the soil), and storage conditions (e.g. by covering manure and thus preventing N losses by NH3 volatilisation).

2.4 Safemanure / ReNure

Within the Nitrate Directive livestock manure is defined as: *'livestock manure': means waste products excreted by livestock or a mixture of litter and waste products excreted by livestock, even in processed form* (article 2g of Nitrate directive). This definition is to be interpreted very strictly.

The implication of the strict interpretation of the definition of livestock manure, means that recycling-derived fertiliser products which are derived from animal manure will remain to be regarded as animal manure by definition, even if they have similar properties as chemical fertilisers. This will be the case for e.g. composts and digestates based on animal manure, but also for liquid products like mineral concentrates, ammonium nitrate and ammonium sulphate. For that reason, they also remain subject to the maximum application limit of 170 kg N per hectare from the Nitrate directive, limiting their marketability.

The production of high quality recycling-derived fertilisers (such as ammonium nitrate, ammonium sulphate) that cannot be distinguished from chemical fertilisers had not been foreseen. The rationale behind the application standard for animal manure is that because of the inherent properties of the livestock manure an application above 170 kg N would result in an undesirable losses by leaching to the water system. The high quality ammonium salts do not have the same properties as manure. Therefore it would not be necessary to impose the application measures for manure on these products. The legal status of animal manure of those products, will also limit possibilities for transport, etc.

because they remain animal manure in case the end point in the manufacturing chain has not been declared.

The consequence is that there is no fair level playing field for fertilisers recovered from animal manure, even if the final properties and purity are similar to chemical fertilisers. Therefore, the EC has launched a study to evaluate the effectiveness and environmental safety of manure-derived fertilisers, the Safemanure project.

The results of the Safemanure project have been published by the Joint Research Centre (Huygens et al., 2020). Within that scope, the authors explored which criteria could allow nitrogen (N) fertilisers that are partially or entirely derived from manure, to be used in areas with water pollution by N following the same provisions applied to N containing chemical fertilisers in the Nitrates Directive (91/676/EEC), while ensuring adequate agronomic benefits.

Fertilising products that meet the criteria are referred to as "REcovered Nitrogen from manURE (RENURE)". In the final report the following criteria for RENURE were formulated:

(i.) RENURE is obtained through a process where the handling chain for the manure(s) applied as input material involves a physical, chemical, or biological process step for the treatment of manure other than solely mixing, blending, drying, rewetting, granulation and/or storage, that increases the concentration of mineral N, urea N and/or crystal-bound N (% relative to total N) compared to the input material(s). The production process results in materials of a consistent quality that is in compliance with all other criteria.

(ii.) RENURE materials have a mineral N:TN ratio ≥ 90% or a TOC:TN ratio ≤ 3. This criterion is evaluated by correcting for any N derived from concentrated N materials (>3% N, dry matter basis) that classify as products or by-products and not originating from manure.

(iii.) RENURE materials do not exceed the following limit values:
- Cu: 300 mg kg-1 dry matter; and
- Zn: 800 mg kg-1 dry matter.

(iv.) Member States should ensure that the timing and application rates of RENURE and other fertilising materials are synchronised with plant NPK requirements to minimise nutrient leaching and run-off losses. In accordance with the application of good agro-environmental practices, this involves in particular:
- the specification of information on the content of N, P2O5, and K2O in RENURE materials for any of these elements where the concentration exceeds 1% of dry matter, with a maximum deviation of 25% from the actual value, in order to monitor and record the field nutrient budget;
- unless inappropriate, maintaining a living plant cover on the land for as much of the year as possible or equivalent measures.

(v.) Member States should prevent and minimise NH3 emissions during RENURE application on field (by injection, immediate incorporation of surface-applied materials or equivalent measures), especially for RENURE N fertilisers that have
- > 60% of the N present in N forms other than NO3--N, and
- a pHH2O > 5.5.

(vi.) Member States should prevent and minimise emissions to air resulting from storage through enforcing appropriate storage conditions of RENURE.

Thereby it was noted that the RENURE involves the processing of livestock manure, an animal by-product. RENURE materials will remain subject to the controls of Regulation EC/1069/2009 and Regulation EU/142/2011 on animal by-products (ABP), until the end point in the manufacturing chain, as defined in these Regulations, is reached. Similarly, the RENURE proposals have been developed taking into account the provisions of the National Emissions Reduction Commitments (NEC) Directive (Directive (EU) 2016/2284) that control the emissions of air pollutants, including ammonia.

For ammonium salts that are recovered from manure or processed manure through a process of stripping and scrubbing this end point in the manufacturing chain under the ABP regulations does not apply: the ammonium salts are not considered as an animal by-product but as a residue product of air purification. Ammonium salts may be used as a component for EU fertilising products, provided that they meet the criteria for the CMC 15 that is in preparation.

The criteria for RENURE products have not been implemented yet. It is still under discussion whether this will be implemented by an amendment of the Nitrate Directive, via the country specific Nitrate programmes or by derogation measures.

3 National legislation on fertiliser use

3.1 Introduction

The Nitrate directive has to be implemented in all EU member states and within that scope all member states are obliged to make Action programmes for Nitrate Vulnerable Zones (NVZ) in which they describe how the Nitrate directive is implemented in their country. These action plans also take into account measures for the Water Framework directive.

Several overviews have been given, in which action programmes of EU member states have been compared (e.g. Van Grinsven et al., 2012; Ten Berge & Van Dijk, 2009, Gault et al., 2016). In this chapter, we will give a short overview of the headlines of the national legislations in which the Nitrate directive has been implemented in the relevant countries within NW Europe.

In the former chapter, it has already been described that the following elements are part of the action plans:

- Derogation: a maximum application limit of 170 kg N per ha in animal manure is prescribed for NVZ, but exceptions (so called derogations) are supplied for several countries. Within these countries it is allowed to apply higher amounts of N with animal manure in the NVZ, provided that this will not lead to an increase of the risk for exceeding the critical nitrate limit of 50 mg NO3 per litre. Van Grinsven et al. (2012) gave an overview of the derogations for grassland (mostly dairy farms) in nitrate vulnerable zones of several countries that were of relevance in 2009 (Table 3.1).
- Derogations are granted at farm level, except in Flanders (Belgium), and mostly apply to farms with at least 70-80% of farm land in use for grassland. Flanders has a derogation at field level and includes some arable crops.
- N application standards: the action programmes in Flanders and the Netherlands contain crop specific N application standards for the combined input with manures, mineral fertilisers and other sources (Ten Berge & Van Dijk, 2009). The application standards apply to fertiliser equivalent (FE) N, being the sum of N in mineral fertilisers plus N fertiliser equivalents given as manures and other sources. In 2011 a new system has been introduced in Flanders, in which farmers can choose between a fixed total nitrogen amount of FE N values for organic fertilisers per crop.

Table 3.1. Area of nitrate vulnerable zones per country and application limits for manure (in kg N/ha) in 2009 within the scope of the obtained derogation (European Commission, 2011, cited by Van Grinsven et al., 2012).

	Nitrate Vulnerable Zones area (%)	Application limit for manure (kg N ha^{-1})	Share of Agricultural land (%)	Share of farms (%)
Belgium	68			
Flemish Region	100	250/200[1]	12	10
Walloon Region	42[2]			
Denmark	100	230	4	3.2
France	45	170	0	0
Germany	100	230	< 1	< 1
Ireland	100	250	8	8
Netherlands	100	250	45	32
United Kingdom	39	250	1.5	1.3

[1] Also a derogation for some arable crops. [2] Situation in 2007 (Anonymous, 2008b).

- In Ireland, the Netherlands and UK, standards are differentiated for some crops with actual yield level and target and in Ireland and the UK the standards also depend on the soil N status and cropping history.
- In Germany there are no legal N application limits for total or FE nitrogen. Instead, there is a restriction on net N surplus at farm level in combination with statutory FE values. The N surplus should not exceed 60 kg N per ha.
- France did not negotiate with the EU Commission about a derogation with respect to the application limit of 170 kg N/ha with animal manure. It does not prescribe application standards in its' action programme for nitrate vulnerable zones. Fertiliser equivalents vary with crops and application period but have no legal status. Total N inputs are limited only in areas where nitrate concentrations in ground or surface water are high. This limit is 210 kg N/ha in so called complementary action areas (Zones d'Actions Complémentaires), which are used for drinking water and face at the same time high nitrate values. In some watersheds with nitrate in surface water exceeding 50 mg N/l total N inputs are restricted to values as low as 140 kg N/ha.
- Fertiliser equivalents of manure: because not all N in manure is available for plant uptake in the year of application, most countries work with the concept of Fertiliser Replacement Values or Fertiliser Equivalents (FE's) in the application standards for N. FE's for a certain type of manure are rather similar in different countries, but differences are there (table 3.2). For cattle and pig slurry the FE's are relatively high in Denmark and low in United Kingdom and Ireland. In France, the FE's have no legal status.

Table 3.2. Statutory N fertiliser equivalents (in %) for application of several manure types per country (Webb et al., 2013; cited by Van Grinsven et al., 2012).

	Cattle slurry	Pig slurry	Layer solid manure	Broiler solid manure
Netherlands	60	60–70	55	55
Flemish Region	60	60	30	30
Denmark	70	75	65	65
France*	50–60	50–75	45–65	45–65
Germany	50	60	30	30
United Kingdom	20/35	25/50	20/35	20/30
Ireland	40	50	50	50

* No legal status.

3.2 The Netherlands

In the Netherlands, fertiliser application is regulated by the Fertiliser Act (Meststoffenwet) and the accompanying Implementation Decree (Uitvoeringsbesluit Meststoffenwet) and Implementation Regulation (Uitvoeringsregeling Meststoffenwet).

The allowed fertiliser application at farm level is regulated via a set of application standards:

1. The first one is an application standard for manure, based on total N. This is the implementation of the prescribed standard of 170 kg N/ha for N in the Nitrate directive. Derogations are available for dairy farms with >80% grassland (in March 2022 not yet for 2022 and following). They are allowed to apply 230-250 kg N/ha via animal manure, in dependence of soil type.
2. The second application standard is for the sum of N applied with animal manure (for which fertiliser equivalents are used), mineral fertilisers and other fertilisers (including compost; also based on fertiliser equivalents). This group of application standards is highly differentiated at the basis of the crop and soil type. A long list with N application standards per crop and soil type is available. A short extract for major crops is shown in table 3.3.
3. The third application standard applies to P_2O_5. These standards differ at the basis of the P status of the soil and the crop type (grassland versus arable and/or horticultural crops; table 3.4 and 3.5).

Soil analysis is only required for the use of sewage sludge

Table 3.3. Application standards for N (based on effective N) in the Netherlands for some major crops per soil type (situation 2019-2021; www.rvo.nl).

Crop	Sand	Clay	Peat
Grassland			
• Grazing & mowing	250	345	265
• Mowing	320	385	300
Maize	112-140	160-185	150
Potatoes			
• Ware	184-235	250	245
• Starch	184-230	240	230
Sugar beets	116-145	150	145
Winter wheat	160-190	245	160
Spring barley	80	80	80
Onions	120	120	120

Table 3.4. Phosphate application standards for grassland in 2020 (www.rvo.nl).

P-class	P-AL-value	Amount of P2O5 (per ha)	Protocol for sampling
High	> 50	75 kg	No
Rather high	41 t/m 50	90 kg	Phosphate differentiation and Derogation, or Phosphate poor and Phosphate fixing
Neutral	27 t/m 40	95 kg	Phosphate differentiation and Derogation, or Phosphate poor and Phosphate fixing
Low	16 t/m 26	105 kg	Phosphate differentiation and Derogation, or Phosphate poor and Phosphate fixing
Poor	< 16	120 kg	Phosphate poor and Phosphate fixing

Table 3.5. Phosphate application standards for arable land in 2020 (www.rvo.nl).

P-class	Pw-value	Amount of P2O5 (per ha)	Protocol for sampling
High	> 55	40 kg	no
Rather high	46 t/m 55	60 kg	Phosphate differentiation and Derogation, or Phosphate poor and Phosphate fixing
Neutral	36 t/m 45	70 kg	Phosphate differentiation and Derogation, or Phosphate poor and Phosphate fixing
Low	25 t/m 35	80 kg	Phosphate differentiation and Derogation, or Phosphate poor and Phosphate fixing
Poor	< 25	120 kg	Phosphate poor and Phosphate fixing

3.3 Belgium

Fertiliser application in Belgium (Flanders) is regulated via the Manure Decree (Mestdecreet) that contains application standards based on

- total N in manure (125 kg N for crops with low N demand, other crops 170 kg per hectare),
- the FE of N from manure, other fertilisers (like compost) and mineral fertilisers. A distinction is made for soil type (sand or no-sand) and crop groups. Eighteen crop groups and eleven crop combinations are distinguished.
- Total P in fertilisers. Eighteen crop groups are distinguished, and a distinction is made in classes of soils, depending on the P-status.

The total amount of allowed N is mostly higher than the maximum allowed amount of N applied with manure. This means that, if the maximum allowed amount of N with manure is applied, additional N may be given with mineral fertiliser or other fertilisers, like compost.

3.4 France

Fertiliser application in France is regulated only by the application standard of 170 kg total N per ha for manure. There is no general N standard for the total N input with animal manures and other (mineral) fertilisers at national scale or in Nitrate vulnerable zones (NVZ's). Total N inputs are limited only in areas where nitrate concentrations in ground or surface water are high. This limit is 210 kg N/ha in so called complementary action areas ('Zones d'Actions Complémentaires'), which are used for drinking water and face at the same time high nitrate values. In some watersheds with nitrate in surface water exceeding 50 mg N/l total N inputs are restricted to values as low as 140 kg N per ha for arable, pig

and poultry farms (maximum 40 kg N per ha as mineral fertilisers) and 170 kg N per ha (including excretions on pastures) for cattle farms (maximum 70 kg N per ha as mineral fertilisers) (Van Dijk & Ten Berge, 2009).

The nitrogen balance is used as a basis for N fertiliser recommendations and is calculated from (i) the foreseeable nitrogen requirements of the crops, and (ii) the nitrogen supply to the crops from the soil and from fertilisation (organic and mineral) (Hermann & Hermann 2019). Fertiliser equivalences are used for organic manures and vary per crop, but have no legal status (Comifer, 2011 cited by Van Grinsven et al., 2012).

3.5 Germany

At national scale the Fertilisation Ordinance (Düngeverordnung, or DüV) is in force, but the States (Länder) have their own regulations. The DüV does not regulate the use of total N with fertilisers by fixed application standards. Instead, the basis of the DüV is good agricultural practice aiming at:

1. Yield stability and product quality
2. Conservation of environmental values and
3. Maintenance of soil fertility (Van Dijk & Ten Berge, 2009).

According to Van Dijk & Ten Berge (2009) the state or regional authorities need to publish fertilisation recommendations based on the DüV and are responsible to implement measures enforcing compliance with regulations. At the basis of these fertiliser recommendations, farmers have to make a fertilisation plan or nutrient management plan.

In addition, farmers have to make a nutrient balance at field level every year, in which they include inputs with fertilisers (organic and mineral) and legume crops and outputs with harvested products. Calculated N surpluses are averaged over the three most recent years and may not exceed a threshold of 60 kg N per ha (situation 2009-2011). On the N balance of vegetable crops a loss term of 50-120 kg N per ha (annual basis) is subtracted to account for the inevitable losses associated with vegetable crops.

No penalties are given when the threshold level is exceeded.

Soil analysis is required for the use of biowaste (including compost).

3.6 Ireland

Ireland has also a derogation of 250 kg N per ha for grassland on dairy farms, which is only of relevance for 8% of the agricultural area in the country (situation of 2009; EC, 2011 cited by Van Grinsven et al., 2012).

In addition, N application standards are included in the action programmes for the Nitrate directive. These standards are based on total N and are relatively low, if compared with other countries in NW Europe (table 3.7).

Table 3.7. Nitrogen application standards (kg N per ha per year) for some major crops in the 4th action programmes for the Nitrate directive expressed either as fertiliser equivalent (FE) or total N (after Van Grinsven et al., 2012).

		Soil	Grass: graze and cut	Forage maize	Winter wheat	Potato (ware)	Sugar beet
Netherlands	FE	sand	260	150	160	245	145
	FE	clay	310	185	220	250	150
Denmark[1,2]	FE	sand	310[5]	150	[3]150	140	110
	FE	clay	330[5]	155	[4]180	140	120
Flemish Region	FE[8]	sand	235	135	160	190	135
	FE[8]	clay	245	150	175	210	150
	total	sand	350	205	200	260	205
	total	clay	360	220	215	280	220
United Kingdom	total	all	330	150	220	270	120
Ireland[6]	total	all	[7]306	140	180	145	155

[1] 0–5 % clay, not irrigated, [2] > 15 clay, not irrigated, [3] fodder quality, [4] baking quality, [5] for grass with clover 62–227 kg N ha^{-1}, depending on % clover, [6] soil nitrogen index 2 for arable crops, [7] for stocking rate between 170 and 210 kg ha^{-1} N per year, [8] valid from 2011 and without catch crop.

3.7 UK

The derogation in the UK was also 250 kg N per ha for grassland on dairy farms, but that represents only 1.5% of the agricultural land in the country (situation of 2009; EC, 2011 cited by Van Grinsven et al., 2012).

As in Ireland, these standards are based on total N. However, the allowed N applications for some crops are significantly higher than in Ireland. This is for example the case for winter wheat and ware potatoes. The application standards are 220 and 270 kg N per ha respectively in the UK and are relatively high, if compared with other countries in NW Europe (table 3.7). It should be noted that after the Brexit the Waste Framework directive and the Nitrate Directive do no longer apply to the UK.

4 Consequences for the use of RDF's

4.1 Composts

For the use of compost, a distinction has to be made between composted manures and composted biowaste (i.e. household and green waste). If we have a look at the composts that are used in the ReNu2Farm project (table 4.1), the composts 2-3-4 are based on manure and the compost 1 is based on household waste.

Table 4.1 Average contents (in % of fresh matter) of dry matter (DM), C organic and macronutrients in the composts 1 (household waste),and compost 2,3,4 (composted animal manure), analysed by laboratories of University of Ghent and/or Limerick and of Arvalis (source: Saju et al., 2021).

Product	laboratory	DM	Corg	N	P_2O_5,	K2O	SO3	CaO	MgO	Na2O
Compost 1	UGhent	65	19	2.6	1.9	1.8	1.7	3.2	0.3	0.3
Compost 2	UGhent	33	12	1.4	1.6	0.8	1.1	1.3	1.0	0.1
	Arvalis	33	12-13	1.6-1.8	1.8	1.1	0.6	1.7	0.9	0.2
Compost 3	UGhent	56	21	2.2	1.5	0.9	1.2	0.0	0.8	0.3
	Arvalis	33	11-21	1.3-2.8	1.6-3.2	1.1-1.4	1.9	1.7	0.8	0.4
Compost 4	UGhent	50	16	1.7	1.5	1.9	1.3	1.0	0.6	0.4
	Arvalis	32-63	11-14	0.9-1.7	1.6-3.2	0.8	1.7	1.1	0.9-1.4	0.9

Composted manure is regarded as manure from a legal point of view. The application and handling of composted manure should be in accordance with the animal by-product legislation. The amount of composted manure that may be applied is regulated by the application rate of 170 kg N per hectare from the Nitrate Directive.

In some countries, the use of composted manure is also regulated by application standards for P. In the Netherlands, the P application standard on soils with a high P status is only 40 kg P2O5 per ha for arable crops. If the application of compost from animal manure is limited to a dose of 40 kg P2O5 per ha, the N application is only 35 kg N per ha. This 35 kg N has to be subtracted from the application standard of 170 kg N per ha, which means that in addition 135 kg N per ha may be applied via animal manure in addition to the composted manure.

The application of household and green waste compost in agriculture is regulated at the national level and differs between the member states. In some countries compost is considered waste and application is under strict control. The use of compost is in practice limited to the country where it is produced because of differences between member

states in standards and regulations (input sources, criteria on heavy metals and organic microcontaminants, process requirements), logistic and administrative barriers for the export of a waste product, and the voluminous nature of the product.

Third party certification of compost is necessary in some countries (Be-Flanders, UK) or beneficial (Germany: no soil analysis required for RAL compost). In the Netherlands compost has to comply to the Fertiliser Act. In France, compost has to comply to NFU norms or have obtained homologation. In Ireland, standards and norms are part of waste management certificate of producer.

The volume of compost applied is limited by application rates for N and/or P in some countries (Netherlands, Belgium-Flanders), or by a total amount limitation (UK, Germany).

Nitrogen (and phosphorus) fertiliser equivalent values apply, but these differ between member states (For N: 10% in the Netherlands, 15% in Flanders, and 0-5% UK; For P 50% in the Netherlands, Flanders and the UK).

The consequence of the last remark is that a certain application with compost (e.g. 20 tonnes per ha) leads to different amounts of the so-called 'effective N' applied with that compost in the various countries. If 20 tonnes of household waste compost is applied, this results in an application of 52 kg total-N (of relevance for France), 5.2 kg effective N for the Netherlands and 7.8 kg effective N for Flanders.

As of 16 July 2022, compost that complies with the prerequisites of the regulation EU/2019/1009 on EU fertilising products can be used for the production of soil improvers and organic fertilisers with CE marking, which will automatically have an end-of-waste status. It is not yet clear how the different member states will regulate the **application** of EU fertilising products that are produced from compost.

4.2 Ashes

Ashes from the incineration or gasification of biowaste, sewage or manure are considered waste and can only be used as a fertiliser if authorised as such. Germany and the UK have a limited authorisation of ashes as a fertiliser whereas Flanders and France have given derogations the ashes from specific producers (De Leeuw, 2019; Van Schöll & Postma 2022-II). As of 16 July 2022, ashes that comply with the prerequisites of the regulation EU/2019/1009 on EU fertilising products can be used for the production of soil improvers and organic fertilisers with CE marking, which will automatically have an end-of-waste status.

The Nitrate Directive does not pose any restrictions on the use of ashes as a fertiliser. Ashes are mostly used as a PK-fertiliser and/or for their neutralising value. In countries where the ashes are authorised ánd where application standards for phosphate are in place (e.g. in Flanders), the allowed doses of ashes are limited by the P application standards. This is for example the case for poultry litter ash in Belgium-Flanders (Van Schöll & Postma 2022-II).). For the use in Belgium-Flanders a valid 'raw material certificate' (a so called 'grondstofverklaring') delivered by OVAM is obligated, and in addition, the product should meet the criteria of VLAREMA 6. Within that scope, maximum levels for i) heavy metal contents in the product and ii) heavy metal dosage to agricultural land should be met. The maximum limits for the heavy metal contents are based on the assumption that 2 tonnes per hectare per year of the product is applied. However, because of relatively high P and K contents, a dosage of 2 tonnes per hectare per year is too high from a viewpoint of 'good agricultural practice', because the P and K dose would have been 178 kg P_2O_5 and 168 kg K_2O per ha (table 4.2). With a 'normal' dose of 1 tonnes per hectare, the maximum dosage level is met (89 kg P_2O_5 and 84 kg K_2O per ha). In spite of the fact that the upper limit for the Zn content in the product is exceeded, a 'raw material certificate', and the resulting end-of-waste status, was obtained for Poultry Litter Ash in 2018 (De Leeuw, 2019).

Table 4.2. Average contents (in % of fresh matter) of dry matter (DM), organic matter (OM) and macronutrients in the ashes the incineration of sewage sludge (ash 1) poultry manure (ash 2) gasification of sewage sludge with green waste (bed ash 3 and fly ash 4) or sewage sludge (ash 5), analysed by laboratories of University of Ghent and/or Limerick and of Arvalis (source: Saju et al., 2021).

Product	laboratory	DM, %	OM, %DM	Corg	N, %	P2O5, %	K2O, %	SO3, %	CaO, %	MgO, %	Na2O, %
Ash 1	UGhent	100	0,01	0	0,0	14,9	0,8	12,5	8,8	1,8	15,9
	ULimerick	100	n.d.	n.d.	0,0	19,2	1,6	7,5	14,4	2,5	13,5
Ash 2	UGhent	94	3,8	0,64	0,0	12,1	8,4	6,5	23,2	4,8	1,8
	Arvalis	94	2,6	0,17	0,0	12,6	16,1	0,0	21,4	5,5	0,0
	ULimerick	100	n.d.	n.d.	0,0	12,6	12,8	7,8	21,8	5,8	1,9
Ash 3	UGhent	100	0,3	0,02	0,0	1,2	1,0	1,7	0,6	0,1	0,1
Ash 4	UGhent	89	12	5,2	0,0	0,7	1,9	2,8	9,4	0,7	5,3
Ash 5	UGhent	100	5,5	14	0,2	15,3	0,6	6,0	18,9	1,6	0,4

4.3 Struvite

A distinction should be made between struvite derived from animal manure and struvite derived from sludge treatment (table 4.3). Struvite from the treatment of manure is legally still regarded as manure, following the definition of manure in the Nitrate Direction. The application volume of manure derived struvite is regulated by the application rate of 170 kg N per hectare from the Nitrate Directive. The application and handling of manure derived struvite should be in accordance with the animal by-product legislation.

Struvite derived from sludge treatment (sewage or biowaste) is a biowaste and can only be used as a fertiliser if authorised as such. This is of relevance for the struvites considered in ReNu2Farm (table 4.3). As of 16 July 2022, struvites that comply with the prerequisites of the regulation EU/2019/1009 on EU fertilising products can be used for the production of soil improvers and organic fertilisers with CE marking, which will automatically have an end-of-waste status. When transported as a component for fertiliser production, the struvites will still be regarded as a waste product.

Table 4.3 Average contents (in % of fresh matter) of dry matter (DM), organic matter (OM) and macronutrients in the struvites derived from municipal waste water (struvite 1) and food waste processing (struvite 2) , analysed by laboratories of University of Ghent and/or Limerick and or Arvalis (source: Saju et al., 2021).

Product	**laboratory**	***DM, %***	***OM %DM***	**Corg %DM**	**N, %**	**P2O5, %**	**K2O, %**	**SO3, %**	**CaO, %**	**MgO, %**	**Na2O, %**
Struvite 1	UGhent	*61*	*27*	0,11	5.5	33.9	0.1	0.0	0.0	17.4	0,0
	Arvalis	*55*	*0.84*	0.42	5.7	28.4	0.1	0.0	0.5	14.9	0,0
	ULimerick	*51*	*18*	n.d.	5.1	6.0	0.1	0.0	0.0	15.6	0,0
Struvite 2	UGhent	*56*	*16*	0.08	5.1	35.0	2.3	0.0	0.0	17.1	0,0
	ULimerick	*58*	*20*	n.d.	5.1	6.9	1.4	0.0	0.1	16.4	0,0

Not all struvites will meet the criteria of the EU regulation. In that case they should be authorised at the national level. Only Germany and the Netherlands have a (limited) authorisation of struvite as a fertiliser whereas Flanders and the UK have given derogations the struvite from specific producers (Van Schöll & Postma 2022-II).). Struvite is generally considered as a P-fertiliser. In The Netherlands, fertiliser application is limited by application rates for animal manure, effective N and P-total. Because of the market surplus of animal manure and low to negative pricing of animal manure, most farmers prefer to use animal manure as a P-source for the required P fertilisation. In addition, farms that have a derogation for the 170 kg N per hectare from the Nitrate Directive are not allowed to use inorganic P-fertilisers, including struvite. As a result, even though the

use of struvite is allowed, there is no market demand for struvite in The Netherlands. Export of struvite is hampered by the waste status of the struvite.

4.4 Ammonium sulphate

Ammonium sulphate from air treatment installations is considered a waste product and can only be used as a fertiliser if authorised as such. Germany, Belgium and The Netherlands have a (limited) authorisation of ammonium sulphate as a fertiliser (Van Schöll & Postma 2022-II).). This includes ammonium sulphate that is derived from air treatment installations in stables. The Nitrate Directive does not pose any restrictions on the use of ammonium sulphate from airscrubbing as a fertiliser.

Ammonium sulphate can also be produced directly from liquid animal manure through a stripping-scrubbing process (Table 4.4). This product is considered in ReNu2Farm (Saju et al., 2021; Van Schöll & Postma 2022-II).).

As of 16 July 2022, ammonium salts that comply with the prerequisites of the regulation EU/2019/1009 on EU fertilising products can be used for the production of EU inorganic fertilisers with CE marking, which will automatically have an end-of-waste status. It is not yet clear how the different member states will regulate the application of EU fertilising products that are produced from ammonium sulphate that is derived from animal manure. Ammonium slats that are derived from treatment of air resulting from stripping and scrubbing of manure are not considered an animal by-product under the scope of the regulations EC/2009/1069 and EU/142/2011 on ABP. As a discrepancy, these salts are considered as animal manure following the strict interpretation of the definition of livestock manure in the Nitrate Directive. In Germany, the ammonium salts are regarded as inorganic fertiliser components, whereas in the Netherlands and Belgium the definition of the Nitrate directive is followed. In that case, the application limit of 170 kg N per hectare applies.

Table 4.4. Average contents (in % of fresh matter) of dry matter (DM), organic matter (OM) and macronutrients in ammonium sulphate that was stripped/scrubbed from animal manure, analysed by laboratory of University of Ghent (source: Saju et al., 2021).

Product	DM,	OM, %DM	N	P2O5,	K2O,	SO3,	CaO	MgO	Na2O
AS	25	n.d	3,9	0,0	0,0	7,1	0,0	0,0	0,0

In dependence of the composition in relationship with the criteria for SafeManure (paragraph 2.3; mineral N > 90% of total N; Cu and Zn contents should not exceed maximum limits; Huygens et al., 2020), the ammonium sulphate could get the Renure status. In that case, the same provisions apply to the ammonium sulphate as to N

containing chemical fertilisers and it can be applied on top of the application limit of 170 kg N per hectare. In addition, NH3 emissions during application of Renure-products on field should be prevented by injection, immediate incorporation of surface-applied materials or equivalent measures. During storage NH3 emissions from Renure products should also prevented by enforcing appropriate storage conditions (see chapter 2.4). However, because the S content in ammonium sulphate is relatively high in comparison with N, high N doses with ammonium sulphate are not possible because of Good Agricultural Practices.

4.5 Ammonium nitrate

Ammonium nitrate is produced directly from liquid animal manure through a stripping-scrubbing process (Table 4.5). This product is considered in ReNu2Farm (Saju et al., 2021; Van Schöll & Postma 2022-II).)

As of 16 July 2022, ammonium salts that comply with the prerequisites of the regulation EU/2019/1009 on EU fertilising products can be used for the production of EU inorganic fertilisers with CE marking, which will automatically have an end-of-waste status. It is not yet clear how the different member states will regulate the application of EU fertilising products that are produced from ammonium sulphate that is derived from animal manure. Ammonium slats that are derived from treatment of air resulting from stripping and scrubbing of manure are not considered an animal by-product under the scope of the regulations EC/2009/1069 and EU/142/2011 on ABP. As a discrepancy, these salts are considered as animal manure following the strict interpretation of the definition of livestock manure in the Nitrate Directive. In Germany, the ammonium salts are regarded as inorganic fertiliser components, whereas in the Netherlands and Belgium the definition of the Nitrate directive is followed.

The Renure status could also be obtained for ammonium nitrate, provided that it meets the criteria. In dependence of the national / regional application standards for manure and other fertilisers, it could be an advantage that the product is no longer considered as animal manure, because the N could be applied on top of the 170 kg N per ha that may be applied with manure. Because the ammonium nitrate does not contain S, it can be applied in larger amounts than the ammonium sulphate within the recommendations of Good agricultural practice.

Table 4.5. Average contents (in % of fresh matter) of dry matter (DM), organic matter (OM) and macronutrients in ammonium nitrate that was stripped/scrubbed from animal manure, analysed by laboratory of University of Ghent (source: Saju et al., 2021).

Product	DM,	OM, %DM	N	P2O5,	K2O,	SO3,	CaO	MgO	Na2O
AN	23	n.d	8.2	0,0	0,0	0,0	0,0	0,0	0,0

5 Conclusions and recommendations

For the use of recycling-derived fertilisers (RDF's) application limits for animal manure and other organic and mineral fertilisers are of relevance. Within the scope of the Nitrate directive most countries in NW Europe have formulated application standards for animal manure (170 kg total N per ha and 230-250 kg total N per ha for grassland on dairy farms in some countries), but there are differences in the way countries have implemented additional application standards in their national legislations. Some countries have formulated application standards for the summed application of N with animal manure ánd other fertilisers, which are sometimes based on total N (which is the case for UK, Ireland, France and Belgium / Flanders (optional)) and sometimes on effective N (which is the case for Belgium / Flanders (optional) and the Netherlands). Germany is using the N balance in the legislation with respect to the allowed N application, and has formulated maximum amounts for the allowed N surplus. In addition, some countries have formulated application standards for phosphate (e.g. Belgium / Flanders and the Netherlands).

Next to the application limits, countries have also formulated the allowed application periods for various fertilising products. These periods vary between countries, regions, soil types, crop types and fertiliser types (Gault et al., 2016).

When using recycling-derived fertilisers, the application standards for animal manure (based on total N) and/or for the summed N input with animal manures and other fertilisers (based on total or effective N; varies per country) and additional regulations for application periods and/or prescribed ways of storage and application (e.g. ammonia emission should be prevented during storage and application of animal manure and Renure products) should be respected.

The main conclusions per fertiliser type are as follows:

For composts it is of importance whether they are produced from animal manure or from other sources, like green waste or household waste. Composts produced from animal manure have the legal status of animal manure and for that reason the application standard of 170 kg total N per ha is of relevance for that product. That is not the case for composts produced from green waste and household waste. As of 16 July 2022, some of the composts could be used as a component for the production of EU fertilisers with CE marking. In some countries (e.g. Flanders and the Netherlands) the *effective* N applied with compost should be taken into account for the N application standard, while in other

countries (e.g. France, UK and Ireland) the *total* N applied with compost should be taken into account.

Ashes from the incineration or gasification of biowaste, sewage or manure are considered waste and can only be used as a fertiliser if authorised as such. Germany and the UK have a limited authorisation of ashes as a fertiliser whereas Flanders and France have given derogations for the ashes from specific producers. As of 16 July 2022, some of the ashes could be used as a component for the production of EU fertilisers with CE marking. The Nitrate Directive does not pose any restrictions on the use of ashes as a fertiliser. Ashes are mostly used as a PK-fertiliser and/or for their neutralising value. In countries where the ashes are authorised ánd where application standards for phosphate are in place (e.g. in Flanders), the allowed doses of ashes are limited by the P application standards.

Struvite derived from sludge treatment (sewage or biowaste) is a biowaste and can only be used as a fertiliser if authorised as such. This is of relevance for the struvites considered in this project. Only Germany and the Netherlands have a limited authorisation of struvite as a fertiliser whereas Flanders and the UK have given derogations the struvite from specific producers. As of 16 July 2022, some of the struvites could be used as a component for the production of EU fertilisers with CE marking. The fertiliser application is generally limited by application standards for total P and N (total or effective).

Ammonium sulphate and ammonium nitrate can be produced directly from liquid animal manure through a stripping-scrubbing process. Following the strict interpretation of livestock manure in the Nitrate directive, the ammonium sulphate would be considered a manure product, and the application limit of 170 kg N per hectare applies. However, for the use of ammonium salts as a component for EU fertilisers with CE marketing, the ammonium sulphate is regarded as a waste product that does not fall under the scope of the Animal by-product regulations. Countries seem to differ in the definition of the ammonium salt products, with some countries (Belgium, the Netherlands) following the definition of the Nitrate directive, while other countries follow the definition of the Fertilising product regulation. This will also impact the transport and handling of the product as either an ABP or a product. In dependence of the composition in relationship with the criteria for SafeManure, the ammonium sulphate could get the Renure status. In that case, the same provisions apply to the ammonium sulphate as to N containing chemical fertilisers and it can be applied on top of the application limit of 170 kg N per hectare. However, because the S content in ammonium sulphate is relatively high in comparison with N, high N doses with ammonium sulphate are not possible within the limits of the Good Agricultural Practices. Because the ammonium nitrate does not contain S, it can be applied in larger amounts than the ammonium sulphate.

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