Products, by-products and recovered secondary materials from processed animal manure

Phillip Ehlert and Oscar Schoumans

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Abstract NL
Technieken om dierlijke mest en andere biomassa stromen te verwerken om de waardevolle componenten te benutten krijgen steeds meer de aandacht nu makkelijk winbare ertsen en energiebronnen van fossiele herkomst gelimiteerd raken en er meer en meer aandacht gegeven wordt aan terugdringen van uitstoot van CO_2 van fossiele bronnen. Producten van dierlijke mest ressorteren onder diverse stelsels van regels van de Europese Unie. Deze stelsels zijn complex en bevorderen daardoor niet altijd een hergebruik. Dit rapport beschrijft kort welke technologieën er zijn om dierlijke mest te verwerken en welke producten daaruit resulteren. Vervolgens worden Europese wettelijke bepalingen beschreven die op deze producten van toepassing zijn. Deze bepalingen vragen aanpassing aan de nieuwe technologieën voor verwerking van dierlijke mest. Het rapport geeft daarvoor aanbevelingen.

Techniques for recovering nutrients from manure and other biomass streams are getting increasing attention now that easily exploitable sources of minerals and fossil-based energy are becoming limited and increasing attention is being given to reducing CO_2 emissions from fossil fuel. Products of animal manure are governed by different sets of EU regulatory rules. These systems are complex and do not always facilitate reuse. This report briefly describes the technologies that can currently process animal manure and the products resulting therefrom. Subsequently, we will describe the EU legal provisions that apply to these products. These provisions have not been fully adapted to the new technologies for manure processing and the resulting products. The report ends by offering recommendations to facilitate the reuse of nutrients found in the products of processed manure.

Keywords: animal manure, processing, treatment, end-of-waste criteria, standards, Waste Framework Directive, fertilizer regulation, REACH, Animal By-Products Regulation, Nitrates Directive

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Preface

The Ministry of Economic Affairs of the Netherlands is interested in how valuable components from manure can be used and has asked Alterra to prepare a brief overview of the products resulting from processing animal manure and which European regulations are relevant in this context. Alterra was also requested to provide a summary of legal or other barriers that exist in the EU regulations on manure products and/or recovered secondary raw materials. A brief report was requested. This brief report serves a debate within the Standing Committee on Agricultural Research (SCAR) and focusses on nutrients from renewable sources: in particular, animal manure and bio-wastes. Writing a brief report on the products of processed manure and EU regulations related to these products clearly limits an overview of backgrounds and in-depth analyses. The report therefore gives a general synopsis. With this document we hope to contribute to successful debate about facilitating the reuse of nutrients from animal manure and bio-wastes.

Phillip Ehlert & Oscar Schoumans

September 2015

Summary

The Ministry of Economic Affairs asked Alterra to prepare a brief overview of products resulting from the processing of animal manure and their relationship to a number of EU regulations. In particular, Alterra was requested to provide a brief report with a summary of legal and other barriers that exist in the EU regulations on manure products and/or recovered secondary raw materials thereof. The reported outcome of this study serves a debate within the Standing Committee on Agricultural Research (SCAR) and focusses on nutrients from renewable sources: in particular, animal manures and bio-wastes.

Techniques for recovering nutrients from animal manure and other biomass streams are getting increasing attention since easily exploitable sources of minerals and fossil-based energy are becoming limited and increasing attention is being given to reducing CO_2 emissions from fossil sources and valorising biomass and waste streams.

A large volume of biomass in Europe consists of animal manure: in 2011, there was an estimated volume of 7.1 Mt nitrogen, 1.8 Mt phosphate and 8.0 Mt potash. Animal manure is used near its production location. It is estimated that 7.8% of animal manure is now processed. The most commonly used technologies for manure processing are pre-treatment techniques (e.g. using additives), separation techniques that lead to a solid and a liquid fraction, anaerobic treatments, treatment of solid fraction (fibres), treatment of liquid fraction and air cleaning (as part of a manure processing plant). Processing leads to products such as compost, digestate, ammonium sulphate solutions in water, mineral concentrates of nitrogen and potassium, precipitated salts (of, amongst others, magnesium, ammonium, calcium, potassium, phosphate), organo- and organic mineral fertilizers, biochar and ashes. These products serves as fertilizer, soil amendments and liming material.

Products of animal manure are governed by different sets of EU regulatory rules. This report briefly describes how the Waste Framework Directive, Animal By-Products Regulation, fertilizer regulation, Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) and Nitrates Directive steer the use and trade of products of processed manures. These regulatory systems are complex and therefore do not always facilitate the use of renewable nutrients. This report briefly describes what hinders the use and trade of products of processed animal manures and highlights the main legal provisions of the given regulatory instruments. These provisions are not fully adapted to the new technologies for processing manure and creating products thereof. The report ends with proposals to facilitate the reuse of nutrients in products of processed manures.

1 Introduction

Key message 1: Nutrients are becoming a scarce commodity.
Key massage 2: Fertilizer production of nitrogen requires around 1% of the world's energy use.

Europe needs to tackle societal challenges related to ensuring food security, sustainably managing its natural resources, reducing the use of non-renewable energy sources, and mitigating and adapting to climate change while maintaining its competiveness and creating jobs (European Commission, 2012). This is exacerbated by a global population that is expected to increase by more than 30% in the next 40 years, from 7 billion in 2012 to more than 9 billion in 2050. The global population growth by 2050 is estimated to increase food demand by 70% and double the existing demand for meat. The bio-economy's[1] cross-cutting nature offers a unique opportunity to comprehensively address these inter-connected societal challenges (European Commission, 2012).

Agriculture, forestry, fisheries and aquaculture require several essential and limited resources to produce biomass. These include land, sea space, fertile and functioning soils, water and healthy ecosystems, but also resources such as minerals and energy for the production of fertilizers. Their use also involves significant opportunity costs linked to the depletion or loss of ecosystem services. As competing uses of biomass and the legacy of past exploitation place these resources under severe pressure, the EU needs to produce "more with less" and develop smart sustainable farming, fisheries and aquaculture (European Commission, 2012).

One of the limited resources used by agriculture are minerals, also called nutrients.[2] Nutrients are essential to produce biomass and are applied to crops with fertilizers. Globally, about 112 Mt of nutrients were consumed in 2013; this is expected to grow to 120 Mt in 2018 (FAO statistics, Figure 1). In Europe (EU27), fertilizer consumption use in 2012/2013 was as high as 10.6 Mt of nitrogen, 2.7 Mt of phosphate (P_2O_5) and 2.4 Mt of potash (K_2O), but it is not expected to grow in the near future (Figure 1). Global population growth and the demand for food are relatively higher than the expected growth in fertilizer production and consumption. Given that there is also no expected increase in suitable agricultural land, nutrient efficiency must increase.

[1] The bio-economy encompasses the production of renewable biological resources and their conversion into food, feed, bio-based products and bioenergy. It therefore includes agriculture, forestry, fisheries, food and pulp and paper production, as well as parts of the chemical, biotechnological and energy industries (EC, 2012). Bio-based products are wholly or partly derived from materials of biological origin, excluding materials that are embedded in geological formations and/or fossilised, CEN - Report on Mandate M/429

[2] Minerals used to feed crops and animals are called nutrients.

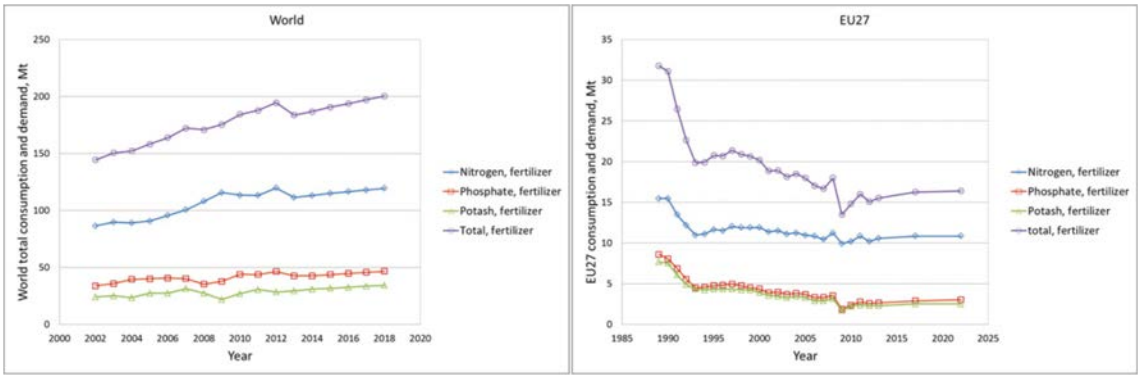

Figure 1 *Nutrient consumption and estimated demand for nitrogen, phosphate (P_2O_5) and potash (K_2O). Totals for the world (left) are based on FAO statistics and EU27 totals (right) are based on statistics from Fertilizers Europe.*

Nitrogen fertilizer production is based on the Haber-Bosch process, which requires 35 (28-50) GJ t^{-1} NH_3 fossil energy. Phosphate and potash are mined from natural mineral resources. Total energy consumption by fertilizer production is estimated at 1.2% of the world's total energy consumption (90% for nitrogen fertilizer production) and is responsible for about the same share of global GHG emissions (Metz et al, 2007).

Nitrogen, phosphate and potash are called the primary nutrients. Crops also require secondary nutrients (calcium, magnesium, sulphur, sodium) and micronutrients (boron, cobalt, copper, iron, manganese, molybdenum, selenium, zinc), which are also mined from natural mineral resources. The current consumption and future demand for fertilizers places these natural resources under pressure. This is especially so for phosphate, potash and essential micronutrients (Table 1).

Table 1

Global production of nutrients, reserves, percentage of production to reserves and years before these natural resources are depleted[3] (USGA, 2015).

Nutrient class	Nutrient	Production 2014, metric tonnes	Reserves, Metric tonnes	Percentage production to reserves (%)	Years before depleted
Primary	Ammonia[a]	144000	large	large	na[b]
Primary	Phosphate rock	220000	67000000	0.3	300
Primary	Potash	35000	3500000	1.0	100
Secondary	Magnesium	6970	2400000	0.3	350
Secondary	Sulphur	72400	5000000000	0.0	69100
Secondary	Calcium (as lime)	350000	large	large	na
Secondary	Sodium	na	large	large	na
Micro	Boron	3720	210000	1.8	55
Micro	Cobalt	112000	7200000	1.6	65
Micro	Copper	18700	700000	2.7	40
Micro	Iron (as iron ore)	3220	large	large	large
Micro	Manganese	18000	570000	3.2	30
Micro	Molybdenum	266000	11000000	2.4	40
Micro	Selenium	na	120000	na	na
Micro	Zinc	13300	230000	5.8	20

[a] Fertilizers production and other uses

[b] N/A: not available

Within this context, the current uses of nutrients for agricultural production require maximal recuperation focussed on recycling nutrients. The European Commission is striving towards a resource efficient Europe (Roadmap to a Resource Efficient Europe (COM(2011) 571)).

Current EU and national policies on environmental, climate, waste handling and renewable energy matters are debated within numerous societal networks. This brief report serves a debate within the Standing Committee on Agricultural Research (SCAR) and focusses on nutrients from renewable sources: in particular, animal manure[4] and bio-wastes.[5] While it is clearly urgent to reuse nutrients from renewable sources, technological incentives are not always supported by national and/or EU regulations. Europe is making progress in developing new and innovative technologies for recovering nutrients. These technologies are imbedded with technologies that use biomass as a renewable energy source. This note describes some general futures of these innovative methods and their products and signals some regulations that hinder the reuse of nutrients from animal manures and products thereof.

[3] Data on reserves are dynamic. Next to a reduction when an ore is mined and/or the extraction feasibility diminishes, additional deposits (known or recently discovered) are developed, or currently exploited deposits are more thoroughly explored and/or new technology or economic variable improve their economic feasibility (USGA, 2015).

[4] 'Manure' means any excrement and/or urine of farmed animals other than farmed fish, with or without litter. This definition is according to Regulation (EC) no 1069/2009 of the European Parliament and of the Council of 21 October 2009 laying down health rules as regards animal by-products and derived products not intended for human consumption and repealing Regulation (EC) No 1774/2002 (Animal By-Products Regulation).

[5] Bio-waste is defined as biodegradable garden and park waste, food and kitchen waste from households, restaurants, caterers and retail premises, and comparable waste from food processing plants. It does not include forestry or agricultural residues, manure, sewage sludge, or other biodegradable waste such as natural textiles, paper or processed wood. It also excludes those by-products of food production that never become waste.

2 Manure processing

Key message 3: Europe can replace nutrients from mineral fertilizer produced with fossil fuels and/or non-renewable resources with nutrients from renewable sources (animal manure and bio-waste).

Key message 4: Innovative technologies are available for processing animal manures and/or bio-wastes into fertilizer products or secondary raw materials.

Key message 5: Innovation of manure-processing technologies is still progressing.

Nutrients from fertilizers could potentially be replaced by nutrients from animal manure. A simple estimate of the available manure production in Europe is 1.4 billon tonnes for 2011 (Fogged et al, 2012). France produces the largest quantity, followed by Germany. This simple estimate shows that the available quantities of nitrogen, phosphate and potash are 7.1 Mt, 1.8 Mt and 8.0 Mt, respectively.[6] In Europe, it is generally accepted that phosphorus and potassium from animal manure can fully replace the nutrients derived from mineral fertilizers. However, views on nitrogen replacement values[7] and nitrogen efficiencies[8] differ (Webb et al, 2010). In general, the replacement value of nitrogen from animal manure is lower than that from mineral nitrogen fertilizer (i.e. 5-85%, value depends on many factors). Farmers are counting nutrients from mineral fertilizers, animal manure and other types of fertilizers (compost[9], digestate[10] and other organic fertilizers and soil amendments). The potential for replacing nutrients from mineral fertilizer with nutrients from bio-waste excluding animal manure in 2025 is estimated at 3% for N, 14% for P_2O_5 and 22% for K_2O (European Commission, 2015).

Animal manures and bio-wastes are used on the farm or nearby the industry where they are produced. The intensification of livestock farms has resulted in greater animal manure production than accounted for in the Nitrates Directive and resulting action plans (see 3.5), and greater than the manure producing farms can use on their land. In this situation, manure needs to be transported to agricultural land on other farms, quite often at considerable distances from the farm where the manure was produced. Processing manure into products with low water contents facilitates transport. Processing manure and bio-waste also quite often serves goals related to waste reduction and energy production from renewable wastes.

Most animal manures are used raw (i.e. unprocessed). However, manure processing is embedded in common agriculture practices. For 2010-2011, Fogg et al (2012a) estimated that 7.8% of livestock manure production was processed. Since then, manure processing technologies have been further embedded in agriculture (e.g. Flanders, the Netherlands, Denmark, Germany). However, statistical data on state-of-the-art manure processing technologies are not available.

[6] The given quantities cannot fully replace the demand for nutrients from regular mineral fertilizers. Next to nutrients from animal manures, farmers still need nutrients from mineral fertilizers. Farmers are using fertilization schemes that account for nutrients from mineral fertilizers, organic fertilizers, soil amendments and other nutrient sources. These fertilization schemes determine total demand for nutrients from all available sources.

[7] Amount of nitrogen from fertilizer that can be replaced by nitrogen from animal manure.

[8] Nitrogen efficiency of manure is the proportion of nitrogen from animal manure that can be recovered over more than one growing season.

[9] Composting is the aerobic degradation of bio-waste to produce compost.

[10] Digestion is the anaerobic degradation in the absence of oxygen to produce digestate. A digestate can be separated into solid and liquid fractions. The solid fraction can undergo further aerobic degradation, which results in compost.

2.1 Techniques

There are numerous techniques for processing animal manure. Annex 1 gives a long list of technologies that have reached the status of practical application. If technologies that are currently under development and being tested on a pilot scale were added to this list, it would be considerably longer.

Manure processing also serves a reduction of volume. Within the context of this report, there is ambivalence about the goals of manure processing techniques. Not all techniques are focussed on maximum recovery of nutrients (and equally valuable organic matter). Sometimes manure processing techniques are used to eliminate minerals from the local agricultural cycle. For instance, nitrification-denitrification processes are used to convert valuable nitrogen into nitrogen gas (N_2). These techniques are in use in France (Brittany) and Belgium (Flanders). Another example is the use of animal manure as fuel, which leads to nitrogen-free ash (techniques applied in the United Kingdom, Germany and the Netherlands).

The most commonly used groups of technologies for manure processing are:
- Pre-treatment techniques (e.g. using additives).
- Separation techniques leading to solid and liquid fractions.
- Anaerobic treatments.
- Treatment of solid fraction (fibres).
- Treatment of liquid fraction.
- Air cleaning (as part of a manure processing plant).

Pre-treatment and separation techniques reduce volume and segregate nutrients, mainly phosphate from nitrogen and potash.

Anaerobic treatment first serves biogas production. Anaerobic treatments might also serve as a tool for removing nitrogen from animal manure or its liquid fraction.

Treatments of solid and/or liquid fractions are more often used to convert animal manure into products that have similarities with mineral fertilizers or secondary raw materials that follow pathways in other processing industries.

Processing facilities need to fulfil specific requirements (e.g. clean air act). Air cleaning becomes an obligation, which results in products that can be reused as fertilizer.
Technologies are often used in cascading processes in which one facilitates the other, but that strongly depends on the local situation.

2.2 Products made from animal manure

Technologies lead to the production of different products from animal manure (and bio-waste). Figure 2 provides an overview of products resulting from applying various technologies to the solid fraction and the liquid fraction of animal manure, respectively. Digestion — often simultaneously with other bio-wastes — is quite often an important part of animal manure processing. Most technologies are also applicable to digestates and their separation products.

Processing technologies lead to a variety of products. Major products (with their potential function for reuse) are:

Processing technologies lead to a variety of products. Major products (with their potential function for reuse) are:

- Compost (organic fertilizer or organic soil amendment).
- Digestate (organic fertilizer or organic soil amendment).
- Ammonium sulphate solutions in water (mildly acidic).
- Mineral concentrates of nitrogen and potassium.
- Precipitated salts: magnesium ammonium phosphate (Mg-struvite), potassium ammonium phosphate (K-struvite), magnesium phosphates, calcium phosphates.
- Organo-mineral fertilizers (NPK fertilizers embedded in organic matter, relatively high nutrient contents).
- Organic fertilizers (organic fertilizers with relatively low nutrient contents).
- Biochar.
- Ash (PK fertilizer, liming material).

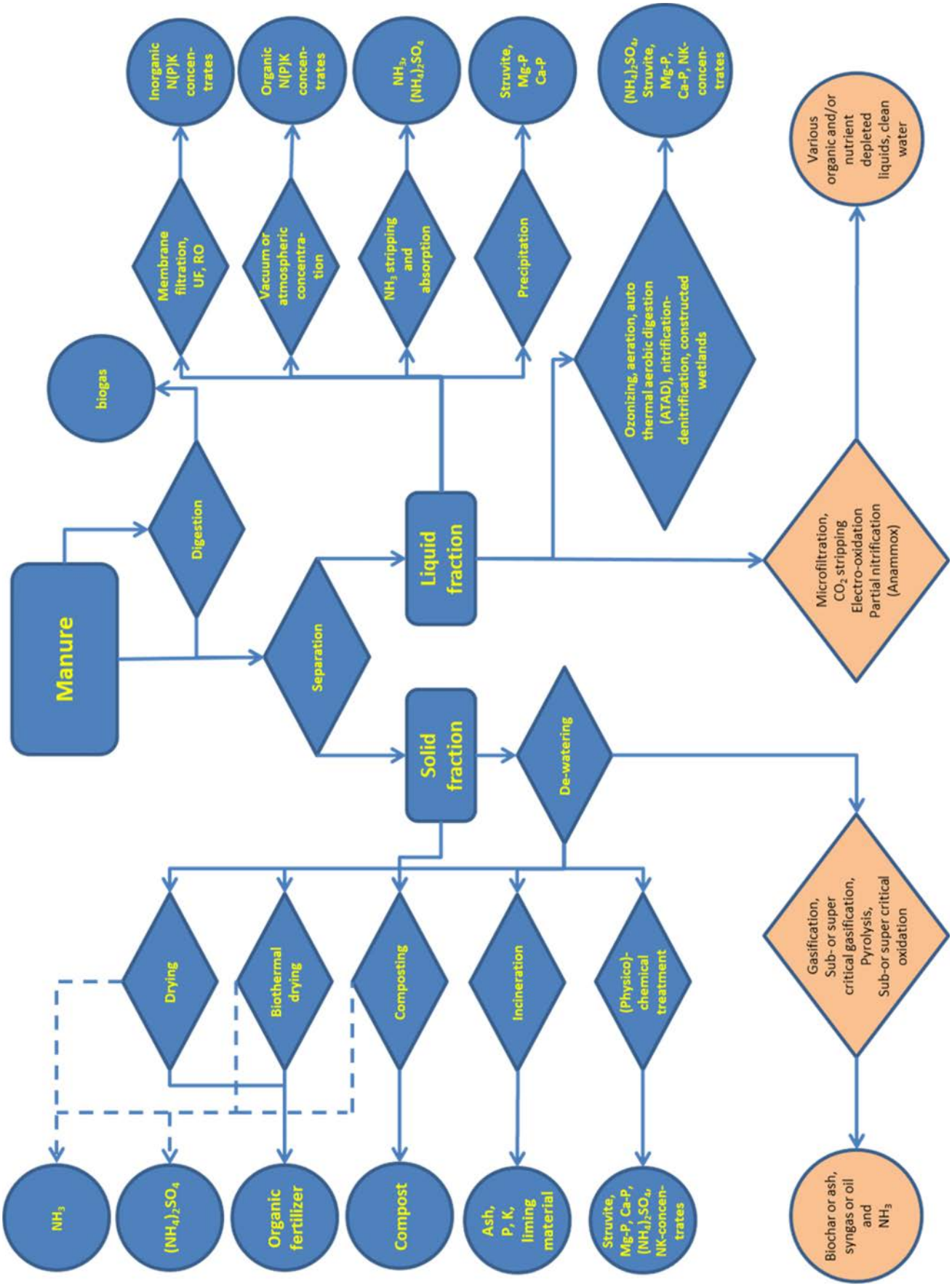

Figure 2 *Processing technologies for the solid and liquid fractions. Blue technologies are implemented in agricultural practice. Orange technologies are being tested on a pilot scale.*

3 EU regulations for products of processed manure and bio-waste

Processing animal manures and/or bio-wastes results in products, by-products and secondary materials.[11] The materials that result from processing animal manure and by-products are controlled by an array of EU regulations. If EU regulations do not apply, national regulations do. In that case, the coordination of national regulations to EU regulations is underway or has yet to be initiated.

The following EU regulations (amongst others) apply to materials of processing animal manure and bio-wastes:

- Waste Framework Directive[12].
- Animal By-Products Regulation[13].
- Fertilizer regulation[14].
- REACH[15].
- Nitrates Directive[16].

The scopes of these directives and regulation differ. The Waste Framework Directive regulates waste management with the ultimate goal of reducing waste production in Europe. The scope of the Animal By-Products Regulation is the prevention of pathogen transmission from animals to humans. The fertilizer regulation facilitate free trade of fertilizers within the EU.[17] REACH's scope is related to managing chemical-related risks for humans, animals and the environment. The Nitrates Directive aims to protect water quality across Europe by ensuring that nitrates from agricultural sources do not pollute ground and surface waters and by promoting the use of good farming practices.

[11] In addition to biogas, heat, water and, occasionally, wastes.

[12] Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives (Waste Framework Directive)

[13] Regulation (EC) no 1069/2009 of the European Parliament and of the Council of 21 October 2009 laying down health rules as regards animal by-products and derived products not intended for human consumption and repealing Regulation (EC) No 1774/2002 (Animal By-Products Regulation) and Regulation (EU) no 142/2011 of 25 February 2011 implementing Regulation (EC) No 1069/2009 of the European Parliament and of the Council laying down health rules as regards animal by-products and derived products not intended for human consumption and implementing Council Directive 97/78/EC as regards certain samples and items exempt from veterinary checks at the border under that Directive

[14] Regulation (EC) No 2003/2003 of the European Parliament and of the Council of 13 October 2003 relating to fertilisers (Fertilizer regulation)

[15] Directive 2006/121/EC of the European Parliament and of the Council of 18 December 2006 amending Council Directive 67/548/EEC on the approximation of laws, regulations and administrative provisions relating to the classification, packaging and labelling of dangerous substances in order to adapt it to Regulation (EC) No 1907/2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) and establishing a European Chemicals Agency

[16] Council Directive 91/676/EEC concerning the protection of waters against pollution caused by nitrates from agricultural sources, (Nitrates Directive)

[17] Regulations for free trade of the products of processed animal manure from EU member states to non-European countries are not given in this note. Specific requirements for animal health and plant protection can lead to more restrictions on import of these products (e.g. in the USA, Canada, Australia, New Zealand, China). These restrictions are not given in this note.

3.1 Waste Framework Directive 2008/98/EC

Key message 6: Products made by processing animal manure are not wastes.

Key message 7: Combining animal manure with bio-wastes can result in materials that are designated as wastes. In this situation, end-of-waste criteria need to be developed to ensure a product or by-product status.

The Waste Framework Directive sets forth conditions for when a production residue is a waste and when it ceases to be waste. It was first adopted in 1975 and the most recent changes were made in 2008. In the ensuing years, there was a shift from primarily sanitary aspects to resource conservation through resource efficiency and waste prevention (European Commission, 2014). The Waste Framework Directive is seen as a legal instrument to promote the reuse of wastes as secondary raw materials. Its general conditions to meet an end-of-waste status (according to Article 5) are:

a. Further use of the substance or object is certain.
b. The substance or object can be used directly without any further processing other than normal industrial practice.
c. The substance or object is produced as an integral part of a production process.
d. Further use is lawful, i.e. The substance or object fulfils all relevant product, environmental and health protection requirements for the specific use and will not lead to overall adverse environmental or human health impacts.

Animal manure and products of processing animal manure and bio-wastes generally meet these requirements provided that agriculturally and environmentally sound application is possible while meeting the general conditions for end-of-waste formulated by the Animal By-Product Regulation (3.2). Generally an end-of-waste state applies to animal manures and products of processed animal manures and bio-wastes. If it does not apply, animal manure and its products are wastes. As such, the notification as ‘waste’ hinders trans-border transport.

Bio-waste is waste. Bio-waste treatment results in wastes unless the conditions of Article 5 are met. Processing animal manure together with bio-wastes can lead to materials that fall under the waste status.

Processing animal manure to produce a fertilizer or soil amendment results in products that have reached the end-of waste status. If these products meet requirements for designation with the EC fertilizer label, EU regulations allows for their free trade within EU. A by-product or product requires registration in REACH.

Within the Waste Framework Directive, animal manure and biodegradable wastes are two different entities. The framework does not categorise animal manure as a biodegradable waste, but does so for compost and digestate. Specific end-of-waste criteria have been developed for compost and digestate.

The next paragraphs summarise relevant EU regulations for processed animal manure and products thereof that:
- Have not reached an end-of-waste status.
- Have reached an end-of-waste status but cannot meet the requirements of eu regulations on fertilisers (by-products and secondary raw materials).
- Have reached (as a product) the status of a regular fertiliser.

Waste

Processed animal manure, of which a use as fertiliser or soil amendment is certain, is a by-product.[18] In general, animal manure is not considered to be a waste, but processes of incineration, landfilling or use in a biogas or composting plant makes animal manures (and products thereof) a waste (Article 2.2.b). Also, if the use of a by-product, secondary raw material or product is not certain, processed animal manure is a waste. In general, the Waste Framework Directive does not acknowledge preparations for reuse, recycling, recovery or disposal as conditions that lift the waste status.

Import and export of wastes under EU28 is governed by a regulation on shipments of waste.[19] This regulation distinguishes reusable wastes from disposable wastes. Since 2007, processed animal manure has been regulated by legislation on animal by-products (1069/2009/EC and 142/2011/EC). Both exporting and importing countries supervise these processes by means of permits.[20]

The Waste Framework Directive applies to digestate and compost. Anaerobic digestion or composting are not yet designated as recycling methods that lift the status of waste. However, end-of-waste criteria have been formulated for compost and digestate (Saveyn & Eder, 2014). These end-of-waste criteria have not yet been implemented in EU regulations (e.g. on the trade of fertilizing materials).

The given provisions are applicable to materials with a waste status in which nutrients are recovered. These are, in general, bio-wastes, biochars and ashes. National authorities can lift the waste status.

By-product[21] or secondary raw material meeting end-of-waste criteria

End-of-waste criteria have been formulated in Articles 6 (1) and 6 (2) of the Waste Framework Directive. Waste ceases to be waste when these conditions are fully met.

[18] Judgment of the Court (Fourth Chamber) of 3 October 2013 (request for a preliminary ruling from the Supreme Court — Ireland) — Donal Brady v Environmental Protection Agency (Case C-113/12) (Environment — Directive 75/442/EEC — Slurry produced in a piggery and stored there pending its transfer to farmers who use it as fertilizer on their land — Classification as 'waste' or 'by-product' — Conditions — Burden of proof — Directive 91/676/EEC — Failure to transpose — Personal liability of the producer as to compliance by those farmers with European Union law concerning the management of waste and fertilisers) (2013/C 344/38)

The Spanish Manure cases (C-416/02 and C-121/03): the court held that manure is not waste when it is used as soil fertiliser as part of a lawful practice of spreading on clearly identified parcels (regardless of whether the parcels are within or outside the agricultural holding that generated the effluent) and if its storage is limited to the needs of those spreading operations.

[19] Regulation (EC) No 1013/2006 of the European Parliament and of the Council of 14 June 2006 on shipments of waste

[20] Permission is required from the exporting member state and a separate and independent permission is required from the importing member state for each load of the processed animal manure . Unprocessed manure (poultry, horse) requires registration in the European Trade Control and Expert System (TRACES). Registration of processed animal manure in TRACES was abandoned in 2011.

[21] By-product: materials that are not the main objective of a production process but can be considered as non-waste by-products (European Commission, 2007).

End-of-waste criteria

Article 6

1. Certain specified waste shall cease to be waste within the meaning of point (1) of Article 3 when it has undergone a recovery, including recycling, operation and complies with specific criteria to be developed in accordance with the following conditions:

(a) the substance or object is commonly used for specific purposes;

(b) a market or demand exists for such a substance or object;

(c) the substance or object fulfils the technical requirements for the specific purposes and meets the existing legislation and standards applicable to products; and

(d) the use of the substance or object will not lead to overall adverse environmental or human health impacts.

2. The measures designed to amend non-essential elements of this Directive by supplementing it relating to the adoption of the criteria set out in paragraph 1 and specifying the type of waste to which such criteria shall apply shall be adopted in accordance with the regulatory procedure with scrutiny referred to in Article 39(2). End-of-waste specific criteria should be considered, among others, at least for aggregates, paper, glass, metal, tyres and textiles.

The European Commission has formulated designated categories of end-of-waste criteria, but there is a lack of criteria for materials of processed animal manure and/or bio-wastes. However, end-of-waste criteria for compost and digestate have been formulated. End-of-waste criteria for struvite (magnesium ammonium phosphate), ammonium sulphate from digestion processes, biochar and ashes are currently being formulated (technical studies conducted by JRC).

In other cases, national authorities have formulated their own end-of-waste criteria,[22] which differ between EU member states. The subsidiarity principle applies. A national authority can allow the processing of other wastes with materials that have reached an end-of-waste status and allow the resulting materials to be used as fertilizers.

Once national regulations about by-products apply to trade and use, trade between member states requires bilateral regulation. Harmonisation of these national regulations is required for free trade within Europe.

Product

The Waste Framework Directive does not apply when products are made by processing animal manure under conditions that the products are not identified as waste or end-of-waste criteria have to be applied. Fertilising materials with the ‘EC fertilizer’ label fall under the fertilizer regulation. Without this label, national regulations are in force.

Registration in REACH is obligatory for by-products, secondary raw materials and products.

[22] For instance, some member states accept the processing of animal manure with bio-wastes and with sewage sludge, and accept the use of the resulting materials as regular fertilizing materials. Other member states ban agricultural uses of these materials.

3.2 Animal by-products

Key message 8: Products made by processing animal manure have to meet regulatory requirements for animal by-products. Trans-border transport leads to an administrative obligation.

Since 2007, the trade and use of processed animal manure has been regulated by legislation on animal by-products (regulations 1069/2009 and 142/2011). These regulations distinguish between three categories of animal by-products. Animal manure is designated as a category 2 material (EU directive 1069/2009). The criteria of this regulation can be seen as end-of-waste criteria for processed animal manure. National authorities supervise the whole process from production to transport, storage and use. Specific regulations apply to imports and exports. Both exporting and importing countries use permits to regulate these processes. Permission is required from the exporting member state and a separate and independent permission is required from the member state that is importing the processed animal manure per load.[23]

3.3 Fertilizer regulation

Key message 9: The fertilizer regulation is strictly focussed on regulating chemical fertilizers and has not yet been adapted to new and innovative processing techniques for nutrient recovery.

The current fertilizer regulation regulates the free trade of fertilizers and liming materials between member states. Currently, it only applies to chemical mineral fertilizers. The quality of the fertilizing materials is regulated by setting standards related to:

- Designating types of fertilizers (e.g. calcium nitrate).
- Data on methods of production and essential ingredients (e.g. chemically obtained product containing calcium nitrate as its essential ingredient and possibly ammonium nitrate).
- Minimum content of nutrients (percentage by weight), data on the expression of nutrients and other requirements (e.g. 15 % N Nitrogen expressed as total nitrogen or as nitric and ammoniacal nitrogen. Maximum content of ammoniacal nitrogen: 1.5 % N).
- Other data on the type designation (e.g. exclusive reservations for certain designated types of fertilizer).
- Nutrient content to be declared, forms and solubilities of the nutrients and other criteria (e.g. total nitrogen; additional optional particulars: nitric nitrogen, ammoniacal nitrogen).

If a fertilizer meets all these requirements, it can be labelled an ‘EC fertilizer’ and its free trade between member states becomes possible.

To meet these standards, protocols for fertilizer analysis and sampling are prescribed. Packaging and blending are also regulated. The fertilizer regulation has resulted in a list of:

I. EC fertilizers,
II. Tolerances,
III. Technical provisions for fertilizers with high ammonium nitrate content (to prevent risks of detonation),
IV. Methods of analysis and sampling,
V. Administrative requirements for new fertilizing material to be labelled as EC fertilizer and for laboratories for compliance control (accreditation requirements).

[23] National regulations apply to unprocessed animal manure. These differ between member states, leading to bilateral agreements between exporting and importing member states.

The fertilizer regulation hinders free trade of products resulting from processing animal manure and bio-wastes in the following ways:

- Data on production method are not in line with the methods designated by the fertilizer regulation. For example, only chemical production processes of (chemical) mineral fertilizers are designated. These processes differ from the processes given in Figures 2 and 3. As production processes of recovery of nutrients of renewable resources are more variable than those of current (chemical) mineral fertilizer production processes, type designation requires more variation and flexibility than is currently allowed for.
- Nutrients of animal or vegetable origin may not be added. This exclusion hinders the use of fertilizer formulations for crop needs.
- Fertilizers with the EC fertilizer label are generally highly concentrated products, while similar types of fertilizing materials recovered from renewable resources quite often cannot meet the minimum requirements.
- Technologies for processing animal manure and bio-waste vary, as does their composition. Products of processed manures and bio-wastes show more variation than current EC fertilizers based on similar compounds. Because of this variation, criteria for tolerances cannot be met.
- Methods of analyses may not be applicable (but these can easily be updated by European Committee for Standardization CEN).

The fertilizer regulation was undergoing a revision process. The European Commission aimed to broaden its scope to include organic fertilizers, organo-mineral fertilizers, organic and inorganic soil amendments, bio-stimulants and additives. However, the revision process has encountered an administrative delay.

Revisions are normally based on the reports of Joint Research Centre (JRC) on fertilizing materials (or wastes meeting end-of-waste criteria). Currently, only the JRC reports on compost and digestate are available (reports on struvite, ammonium sulphate solutions from digestate, biochar and ashes have been drafted). There are no JRC reports for other materials resulting from manure processing technologies.

The fertilizer regulation excludes wastes.

3.4 REACH

Key message 10: Fulfilling the requirements of REACH is an administrative process for which manufacturers and importers of recycled nutrient products are currently not well organized.

Key message 11: There is a need for clarification about which materials that have reached an end-of-waste status are exempted from the obligation to register in REACH.

The Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) regulation aims to improve the protection of human health and the environment through better and earlier identification of the intrinsic properties of chemical substances. This is done by the four processes of REACH: the registration, evaluation, authorisation and restriction of chemicals.[24] REACH also aims to enhance the innovation and competitiveness of the EU chemicals industry.

Waste is excluded from REACH, but substances, preparations and articles require registration. The obligation for registration starts from volumes of 1 tonne/year. Manufacturers and importers of substances in quantities of 10 tonnes or more per annum are required to complete a Chemical Safety Report (to be reviewed by the European Chemicals Agency). Only legal entities in the EU can register

[24] http://ec.europa.eu/environment/chemicals/reach/reach_en.htm

substances. The REACH obligation only come into force after a product has reached an end-of-waste status.

Registration is based on the "one substance, one registration" principle. Manufacturers and importers should jointly register and the information given should be consistent. The identity of the substance must be confirmed by this information. Under REACH, partnerships of industries arise with a form of data sharing through the Substance Information Exchange Fora (SIEFs). Data sharing serves cost control and avoids duplication of research (SIEFs are not installed when a manufacturer applies for registration as an EC fertilizer within the framework of the fertilizer regulation).

EU fertilizers are all registered in REACH. The fertilizer industry jointly registers their fertilizer products.

Products made from recovered nutrients are not exempted from registration in REACH since the products are sold on the European market. Selling a product on the EU market obliges manufactures and/or importers to register it in REACH. Compost and biogas are exempted from the obligation to register (appendix V). However, there is still confusion about which products from manure processing technologies need to be registered. Member states have differing opinions about whether digestate with an end-of-waste status is exempt from registration. Stakeholders have asked the European Chemicals Agency to clarify this point.

Manufacturers and importers of products made from recovered nutrients have to be registered in REACH. However, chemical safety reports are costly, and SIEFs are not yet in place. They have therefore asked that these products be exempted from the obligation to register.

The European Commission published the results of a public consultation on the TOP10 most burdensome legislative acts for SMEs (COM, 2011). REACH ranked in the top 10. The most bothersome were:

1. CE marking rules.
2. Demonstrating conformity in the absence of a harmonised standard.
3. Labelling obligations.

3.5 Nitrates Directive

Key message 12: The Nitrates Directive defines products from animal manure processing as animal manures. The use of animal manure on agricultural land is limited to a maximum of 170 kg N per ha per year.

Key message 13: Chemical fertilizers are not limited to a maximum of 170 kg N per ha per year, but their application rates should be attuned to Good Agricultural Practice.

Key message 14: Products from manure processing can meet similar efficiencies as chemical fertilizers. Designating them as animal manure hinders a resource-efficient reuse.

The Nitrates Directive is an integral part of the Water Framework Directive and aims to protect groundwater and surface water from nitrate pollution. Member states are obliged to:

1. Monitor water quality (NO_3 and trophic status).
2. Designate vulnerable zones for nitrate leaching or apply measures to the whole country.
3. Establish codes for Good Agricultural Practice.
4. Implement compulsory action programmes to control NO_3 leaching.

All member states have implemented these action programmes. An action programme is a set of measures about, for instance:

- Periods when fertilisation is prohibited.
- Minimum storage capacity for livestock manure.
- Rules to control the spread of nutrients near water or on slopes.

All action programmes use the limit of 170 kg nitrogen per hectare per year from livestock manure as set out in the directive. The directive also defines fertilizer, chemical fertilizer and livestock manure.[25] However, these definitions exclude products made by processing animal manure and bio-waste from the definition of a chemical fertilizer manufactured by an industrial process. If processing animal manure leads to a secondary material that is used by industry to chemically produce a fertilizer, the resulting product is a chemical fertilizer.

Therefore their use is limited to the limit of 170 kg nitrogen per hectare per year like non-processed livestock manure. Chemical fertilizers are not bound to this limit but required to use fertilizer in a way adapted to Good Agricultural Practice. Application rates are higher provided that the fertilisation standards of Good Agricultural Practices are met and groundwater and surface water are not polluted by nitrates.

The generic application of the definition of livestock manure means that the following fertilizing materials are all designated as livestock manure and their use is limited to 170 kg nitrogen per ha per year:

- Composts based on animal manure.
- Digestates based on animal manure.
- Mineral fertilizers based on animal manure.
- Organo-mineral fertilizers.
- Organic fertilizers.
- Organic soil amendments.
- Biochar.
- Incineration ashes of animal manure.[26]

However the agronomic effectivity of these fertilizing materials are different from the agronomic effectiveness of the original animal manure. Ammonium sulphate, magnesium ammonium phosphate or dicalcium phosphate made from animal manure cannot be chemical distinguished from their equivalents in the chemical fertilizer industry. The Nitrates Directive defines fertilizer, chemical fertilizer and livestock manure. However, it sets no clear criteria for which manure processing technologies are defined as manufacturing technologies and are thus considered to be an industrialised process.

[25] 'Fertilizer': any substance containing a nitrogen compound(s) used on land to enhance growth of vegetation; it may include livestock manure, the residues from fish farms and sewage sludge;
'Chemical fertilizer': any fertilizer that is manufactured by an industrial process;
'Livestock manure': waste products excreted by livestock or a mixture of litter and waste products excreted by livestock, even in processed form;

[26] Depending on the incineration process and process conditions, incineration ashes can contain nitrogen. Some action programmes include maintenance fertilization for phosphate.

4 Barriers to overcome

Europe has the responsibility to support nutrient recovery techniques as nutrients become a scarce commodity. Current chemical fertilizer production requires fossil methane for production (especially production of nitrogen fertilizers). Current nutrient recovery techniques are often preceded by anaerobic digestion to produce biogas (methane and carbon dioxide), which uses renewable sources of nutrients. An indicative value for the quantity of animal manure that is currently processed is 7.8% of 1.4 billion tonnes (2010). This value is presumed to increase when updated to 2015, due to the increased number of facilities for processing animal manure. However, there is a lack of statistical data on the increase in volume in Europe since EU organisations (e.g. Eurostat) do not monitor these activities. Processing animal manure has an ambivalent aim as not all initiatives strive towards the maximum recovery of nutrients. Some initiatives remove nitrogen through nitrification-denitrification techniques.

The implementation of processing techniques for animal manure faces technical challenges. End users require constant and predictable quality and, last but not least, an acceptable price. To meet this demand, effort is required to cope with the heterogeneous quality of animal manures, disturbances that occur when dealing with a combination of biological, physical and chemical processes and safeguards for product during storage and handling. Additional treatment (e.g. polishing, pelletising, grinding, purification) is required and products need to be tailored to crop requirements with respect to soil quality and climate conditions. The animal manure and bio-waste processing industries are innovative and will tackle major technical challenges.

Europe is now challenged to lift regulatory hindrances in support of markets for nutrient recovered products. We make the following recommendations:

- The complexity of existing regulation on animal manure and bio-waste hinders implementation of nutrient recovery techniques. It is recommended that existing regulations be made more horizontal. Make regulations more coherent.
- Set generic end-of-waste standards for materials resulting from processing animal manure and bio-wastes.
- Harmonise national regulations on fertilizers. Set standards for all fertilizing materials that are traded within a member state and between member states.
- Set standards for the resulting fertilizing materials and not for the animal manures and bio-wastes from which they were made.
- Discard unnecessarily burdensome administrative provisions.

Table 2

Current status of animal manure and products derived from animal manure according to the Waste Framework Directive, Animal By-Products Regulation, fertilizer regulation, REACH and Nitrates Directive.

By-products and products of manure treatment technologies	Waste Framework Directive[1]	Animal By-Product Regulation[2]	Fertilizer regulation	REACH	Nitrates Directive
Compost (organic fertilizer or organic soil amendment)	W	Yes	EoW* criteria formulated but not implemented.	No	Yes
Digestate (organic fertilizer or organic soil amendment)	W	Yes	EoW criteria formulated but not implemented.	**	Yes
Ammonium sulphate solutions in water (mildly acidic)	B, (P)	No	EoW criteria not formulated. JRC study started.	Yes	Yes
Mineral concentrates of nitrogen and potassium	B, (P)	Yes	EoW criteria not formulated.	Yes	Yes
Precipitated salts: magnesium ammonium phosphate (Mg-struvite), potassium ammonium phosphate (K-struvite), magnesium phosphates, calcium phosphates	B, P	Yes	EoW criteria not formulated. JRC study started.	Yes	Yes, if it contains nitrogen
Organo-mineral fertilizers (NPK fertilizers embedded in organic matter, relatively high nutrient contents)	B, P	Yes	EoW criteria not formulated.	Yes	Yes
Organic fertilizers (organic fertilizers with relatively low nutrient contents)	B, P	Yes	EoW criteria not formulated.	Yes	Yes, if it contains nitrogen
Biochar	B, P	Yes	EoW criteria not formulated. JRC study started.	Yes	Yes
Ash (PK fertilizer, liming material)	B, P	Yes	EoW criteria not formulated. JRC study started.	Yes	Yes

1 W: Waste, B: By-product, P: Product

2 Yes, if by-products are processed/produced from animal manure

* EoW: End of Waste

** Compost and biogas are exempted from the obligation to register (appendix V). However, there is still confusion about which products from manure processing technologies need to be registered. Member states have differing opinions about whether digestate with an end-of-waste status is exempt from registration. Stakeholders have asked the European Chemicals Agency to clarify this point.

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Annex 1 Long list of manure processing technologies

Livestock Manure Treatment Technology	
Separation	
	Coagulation flocculation
	Electrocoagulation
	Separation by grate
	Separation by screw pressing
	Separation by sieves
	Separation by filter pressing
	Separation by centrifuge
	Air flotation
	Separation by drum filters
	Natural settling separation
Additives and other pre- or first treatments	
	Acidification of liquid livestock manures
	Liming (pH increase)
	Temperature and pressure treatment
	Other additives
Anaerobic treatment	
	Mesophilic anaerobic digestion
	Thermophilic anaerobic digestion
Treatment of solid fraction	
	Composting of solid livestock manure or solid fractions of livestock manure
	Vermicomposting
	Bio-drying
	Thermal drying
	Pelletising
	Combustion
	Thermal gasification
	Pyrolysis
	Wet oxidation
Treatment of the liquid fraction	
	Microfiltration
	Ultra-filtration
	Reverse osmosis
	Concentration by vacuum evaporation
	Concentration by atmospheric evaporation
	Ammonia stripping and absorption
	Carbon dioxide stripping
	Electro-oxidation
	Ozonising
	Aeration (Anaerobic digestion)
	Auto-thermal aerobic digestion (ATAD)
	Nitrification-denitrification (conventional)
	Partial nitrification – autotrophic anammox denitrification
	Struvite (magnesium ammonium phosphate) precipitation)
	Calcium phosphate precipitation
	Algae production on liquid manure substrates
	Constructed wetlands
Air cleaning (as part of manure processing plant)	
	Air scrubbing
	Air bio-filtration
	Bio-scrubbing (Aerobic biofilter)

Source: Foged et al (2011b)

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