Digestate use on Scottish Farms

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This guide is targeted at Scottish farmers and land managers that are spreading or considering spreading anaerobic digestate (digestate) on their land. It is designed to provide a current review of the risks and benefits associated with using digestate and to establish priorities for ensuring that digestate can be a profitable and sustainable part of the farming system.

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1. What is anaerobic digestion (AD)

1.1 Digestate

Digestate is the term used to describe a range of organic fertilisers derived from the processing of organic material in the absence of oxygen. This is done for two reasons:

Safe, sustainable and profitable waste recycling	AD allows us to treat and sanitise organic wastes that could pose a risk to human and animal health while producing renewable energy and fertilisers. These systems can treat material that otherwise would have to be landfilled or incinerated to protect human health.
Green energy production	AD can capture energy from the digestion process. Some systems use only energy crops and/or animal slurries, which do not legally require pasteurisation before being spread to land.

AD is a managed biological process whereby biodegradable organic material is broken down without oxygen being present, using naturally occurring organisms. The resulting products are biogas and digestate, which is rich in plant nutrients. Importantly, in digestate, a high proportion of these nutrients have been converted by the AD process into plant-available forms, making digestate suitable for use as a replacement for bagged fertiliser used to support crop growth.

Digestate is primarily available as whole liquid digestate (normally referred to as whole digestate). However, it is increasingly common to separate the digestate into a liquid and a solid or fibre fraction. The percentage of dry matter in different digestate types can be seen in Table 1.1.

Table 1.1 Percentage of dry matter in digestate type.

Digestate type	Dry matter (%)
Whole liquid	4 - 7
Separated liquid	< 6
Separated solid/fibre	> 20

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1.2 Understanding Feedstocks

The organic materials that are used in AD processes are called feedstocks. Understanding the best type and mix of feedstocks used to produce your digestate is important if you are to ensure a safe, functional and profitable system.

The feedstock types in your digestate will determine:

The rules and regulations that you must comply with	The type of good practice advice you should seek	The fertiliser nutrient and organic matter content of the final product	Potential risks to your business and the environment

AD plants can broadly be separated into those that accept waste feedstocks and those that do not. This will determine the factors that need to be considered when the resulting digestates are spread to land. Specialist help is often required to determine whether feedstocks are classed as wastes. The most used feedstocks are:

Purpose-grown crops

In Scotland, these are primarily grass silage, energy beet and wholecrop cereals (e.g. hybrid rye).

Agricultural manures and slurries:

These are often used as part of the feedstock in AD processes. However, because of their typically low gas yield, they are usually mixed with other materials such as purpose-grown energy crops.

Agricultural crop residues (production residues):

These are produced as an integral part of the commercial production of agricultural crops. They include damaged or misshapen fruit or vegetables, trimmings and other plant parts, which are not the intended end product (e.g. straw, leaves or tops). They can be collected from the field or from a packing unit, prior to leaving the farm-gate. Some are classed as wastes, therefore, the resultant digestate may be classed as a waste under certain conditions (Section 3). SEPA guidance assists AD plant operators to decide whether feedstock materials are wastes or not (SEPA, 2014).

Domestic and commercial food wastes:

Includes material collected from domestic households, retail premises, restaurants, cafes, hotels, schools and other residential premises. To be acceptable for PAS110-accredited wet AD, food waste must be source separated, which means it has never have been mixed with other non-biodegradable wastes. Some of this waste must be de-packaged before it becomes suitable for AD.

Food and drinks processing wastes:

Includes material such as brewers grain and chaff from distilleries and breweries, butchery wastes, abattoir wastes and waste from vegetable packing and processing factories.

Sewage sludge is commonly treated through dedicated anaerobic digestion plants before land spreading. The resulting material is still considered to be sewage sludge and its use in agriculture must comply with The Sludge (Use in Agriculture) (Amendment) Regulations 1990, No.1263. Any material that contains sewage sludge cannot be considered as digestate and is not covered in this guide.

2. Overview of the market

2.1 Current Market

Currently there are over 80 AD plants in Scotland (with over 600 in the UK as a whole). Over 65% of these plants are fed with non-waste feedstock from the agricultural sector, including slurries, manures and crops including grass silage. The others use food and distillery wastes, either on their own or in combination with non-waste feedstocks.

The Scottish AD sector is currently very mature with, until recently, little market-driven incentive for future growth. Recent sharp increases in fertiliser prices may encourage some further investment in AD, since the financial value of digestates is increasing in line with fertiliser prices. Future growth is likely to be at least partly dependent on the renewal of energy production subsidies, which have been the major financial incentive behind much of the industry to date. **The Green Gas Support System**[2], which provides incentive tariffs for eligible AD plants, opened for applications in November 2021. This source of funding is designed to increase private investment into the sector and encourage further development of the AD sector throughout the UK.

With the Scottish Government banning biodegradable municipal waste from landfill by 2025, there will be an increasing need for local authorities to make use of alternative treatment options, which might provide an additional incentive for growth and change in the AD sector.

For farmers, these changes may result in increased volumes of digestate coming into the market. It is important to thoroughly assess the costs, benefits and risks of each digestate option, open to you, since each one will be different.

The rules and regulations controlling the quality and safety of digestate from AD plants in Scotland are now well established, with the Scottish Environmental Protection Agency **(SEPA)** and other authorities enforcing strict guidelines and regulations to ensure the quality and safety of digestate. It remains important, however, that individual landowners have the knowledge required to ensure that the digestate they spread and the way it is used conforms to these regulations.

2.2 Innovation

Technology within the AD sector is continuing to evolve. One area under current investigation is how to reduce the carbon footprint of AD. The bulky nature of whole digestate means that transport, storage, and supply costs are currently limiting its use to farms, that are relatively close to AD plants. As fertiliser prices rise and consumers look for more sustainable options to synthetic fertilisers, suitably processed digestate could offer an appealing solution. As a result, work is currently being conducted on the viability of processing digestates using techniques like stripping, scrubbing, dewatering, nitrification and pelletising. If successful, this could have a significant impact on the sector with reduced costs for storage, transportation, application and potentially reductions in the carbon footprint associated with digestate processing and use. For examples of work currently being undertaken please visit **CCm Technologies** and **Nawrocki Pelleting Technology Ltd** webpages.

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2.3 Carbon footprint

The growth of the AD sector has been a positive step toward finding a sustainable and safe way of recycling food and other organic wastes. Techniques to determine the carbon footprint of the AD sector, including digestate use are, as yet, relatively undeveloped. It is likely that digestion of food wastes is better for the environment than the material going to landfill, given that the methane produced is captured and used rather than released into the air above landfill sites. It may be the case that digestate production and/or use could reduce a farm's carbon footprint. However, every farm will be different and there is a lack of reliable data and tools to help farmers and AD plant managers make the necessary calculations accurately. There are two key areas to consider in relation to the carbon footprint of using digestates on your farm:

1. The main reason for applying whole and liquid digestates is for the fertiliser nutrients that they contain. Whole and liquid digestates contain very little organic matter, and much of that which is present is quickly broken down, with the carbon being released as carbon dioxide (CO_2) gas. Only fibre digestate applications are likely to contribute meaningful amounts of organic matter to soils.

2. The carbon footprint associated with the transport and spreading of the digestate cannot be ignored. Whole digestates are bulky, their transport and spreading is energy intensive, and this must be considered as part of a carbon footprinting process.

The role of AD and digestates in helping address climate change requires further quantification.

The AD sector is vibrant and evolving and digestate is clearly a useful resource for the agricultural community. The benefits of digestate can be considerable, yet the financial and environmental costs of applying it in inappropriate ways can be high. The following sections of this guidance document are designed to steer you through the information you need to ensure that you make the very best of digestate when using it on your land.


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3. Is digestate a waste or a product?

3.1 PAS110[3] accredited digestate in Scotland

SEPA issued a revised **position statement** in 2017. This allows digestate from AD plants that are PAS110-certified and comply with the terms of the position statement to be spread to land as though it was a product without any additional controls other than those **General Binding Rules**[5] (GBRs) that set out environmental requirements for agricultural land practices.

The SEPA position statement also covers non-PAS110 digestates that are created from manures, slurries and purpose-grown (energy) crops that are sourced on-farm or from a co-operative of farms, where the digestate is used only on the farms within that co-operative (case study on page 20).

SEPA retains the ability to impose stricter restrictions if they perceive a risk to the environment or human health from the land spreading of any type of digestate.

In Scotland digestate will not be regulated as waste if it:

Is based only on non-food waste feedstocks such manures, slurries and purpose-grown crops and is used only on the farm on which the feedstock is produced. Digestates are also unlikely to be classed as wastes if they are produced by a co-operative of farmers and used only on farms belonging to members of that co-operative.

OR

Is certified as compliant with the requirements of the UK Biofertiliser Certification Scheme[6] in accordance with PAS 110 (2014) Specification for whole digestate, separated liquor and separated fibre derived from the anaerobic digestion of source-segregated biodegradable materials (BSI, 2014).

AND

Complies with the requirements of the relevant SEPA position statement (SEPA, 2017): "Regulation of outputs from anaerobic digestion processes". This means that the digestate must be applied in accordance with:

- **all regulatory controls (the Controlled Activities Regulations and NVZ regulations [where applicable]. (Section 5.3);**
- **agricultural best practice as defined in the PEPFAA Code[7] (Scottish Executive, 2005) and the Four Point Plan[8]. (section 5.7)**

Any digestate that does not comply with these controls will be classed as waste and can only be applied to agricultural land in Scotland under a Waste Management License Exemption (Paragraph 7).

Your digestate supplier must be able to provide a current PAS110 certificate or direct assurance that the digestate is derived from non-waste feedstocks and conforms with SEPA's position statement before you accept it for storage or land spreading.

4. Managing hazards and risks

4.1 How do I know it is safe?

This note only covers digestates that comply with the SEPA position statement and are also PAS110-accredited or exempt from the need for PAS110-accreditation (Section 3.1).

The risks from storing and land spreading digestate on your farm include, for example:

Short-term Risk	Long-term Risk
Caused by direct exposure of humans and livestock to digestate.	Gradual build up of heavy metals in soils.

4.2 Short-term Risks

Digestate should never be allowed to come into direct contact with humans or livestock, because it will always pose a potential risk to them, just as farmyard manures and slurries would. There are legally binding regulations that restrict grazing and harvesting after application of digestates made from animal by-products (for example, food waste, food processing wastes, slaughterhouse wastes) and your supplier must make you aware if these extra rules apply to you (Section 5).

Digestate is a biologically active material, which contains high concentrations of plant-available nutrients, especially nitrogen (N). When regulations and good practice are not followed (Section 5), or if digestate is accidently discharged into the environment, there can be significant and immediate negative environmental impacts. Any accidental digestate spills should be responded to immediately, and larger ones (more than 1 or 2 m^3) dealt with as major environmental incidents .

Common sense, following the rules and acting on good practice advice when storing and using digestate will help protect you from short-term risks.

4.3 Long-term Risks

The longer-term risks to human and livestock health include the build-up of microplastics and potently toxic elements (PTEs) in the soil and the release of pharmaceuticals into our agri-food system. There is an additional environmental risk from the excess N and phosphate (P) that can be released into the environment.

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4.3.1 Potentially toxic elements (PTEs) and other persistent pollutants

There are limits on the concentration of PTEs in PAS110-accredited digestates and PAS110 accredited producers must test their products regularly to ensure compliance. Given that the feedstocks for most AD processes are naturally low in PTEs and organic pollutants, few digestate producers have trouble in producing digestate, which also contains low concentrations of these pollutants.

One exception can be the persistent herbicides clopyralid and aminopyralid, which are used to control broadleaved weeds in grassland. These herbicides can persist in grass and animal manures used as feedstocks for AD and can also be present in the digestate product being spread to land. The risks from herbicide contamination of digestate must be considered when deciding where and when to apply that digestate.

Whilst non-accredited digestate producers might not conduct regular testing for PTEs, such testing is strongly recommended, along with the testing of nutrient concentrations required under the **Controlled Activities Regulations** (GBRs) (section 5.3).

The limits on PTE concentrations in PAS110-accredited digestate and the likely low concentrations of PTEs and pollutants in all digestates helps to ensure that long term risks, such as the potential build-up of PTEs and other pollutants in soil remain low. In general the amounts of PTEs applied to land in digestate applications will be similar to those when animal manures and slurries are applied to land.

There are some digestate feedstocks in Scotland that contain elevated levels of one or more PTEs (e.g. distillery wastes are typically high in copper). These wastes are currently mainly spread to land under Paragraph 7 waste management licence exemptions. If these types of wastes are to be used as feedstocks for PAS110 AD systems, they will undergo the same feedstock risk assessment process as other food and food processing wastes do, to ensure that the resulting digestate remains safe, PAS110-compliant and exempt from waste legislation.

For digestates from AD processes that accept distillery wastes as feedstocks under Paragraph 51 exemptions, it is advisable to request a full analysis of the PTEs in the digestate. **If digestate users have a question over the suitability of digestate from a particular source for their farm, then they should seek advice from a FACTS-qualified advisor with expertise in the use of organic materials on land.**

Soil testing and reporting on background PTE concentrations in fields regularly used for spreading organic wastes is becoming increasingly important for compliance. Testing of receiving soils for PTE concentrations should always be considered if there are any long-term concerns with PTE build-up. Additional information on management of PTEs/heavy metals in agriculture is available in **Technical Note TN753: Management of inputs of heavy metals to agricultural soils and crops**[10] from the Farm Advisory Service and **Zero Waste Scotland's Overview: Digestate Safety for Agriculture**[11].

4.3.2 Plastics in digestates

Microplastics remain an ongoing concern for society in general and the amounts found in digestates will depend on the feedstock type.

Following problems in the past, visible plastics (>2 mm) are less of a concern in the quality digestate market in Scotland due to improvements in source separation and on-site quality control measures, which remove plastics from feedstocks and from the digestate. Regular visual inspections of digestate arriving on your farm should always be conducted and you should always be prepared to reject digestate that has unacceptable amounts of any type of visual contaminant.

5. Your responsibilities as a farmer

If using digestates on agricultural land, it is your responsibility as a farmer to ensure compliance with the relevant legislation and to use them according to best agricultural practice. Agricultural best practice guidance applies to all digestate types used in all farm situations and assurance schemes typically require compliance with key aspects of it. You need to understand the nutrient content of digestate and the crop- availability of these nutrients, so that you can effectively match digestate applications with crop nutrient demand. The key pieces of legislation and good practice are summarised here:

5.1 Waste Management Licensing (Scotland) Regulations 2011 (WMLR)[12]

The storage and application of waste digestates to land is regulated by SEPA. To apply waste digestates to agricultural land, the farmer must register a Paragraph 7 Waste Management Licence Exemption (Land treatment for benefit to agriculture or ecological improvement). All applications to SEPA must include a "Certificate of Agricultural Benefit" (prepared by a suitably qualified individual), which demonstrates that the material will result in agricultural benefit or ecological improvement when used as described. Both soil and digestate analysis are required. **The addition of total nitrogen (N) attributable to the use of the waste (and any other organic materials) on land in any 12-month period must not exceed 250 kg/ha.**

5.2 Nitrate vulnerable zones (NVZs)[13]

In NVZs, of which there are **five in Scotland**, the total quantity of N applied in organic materials must be included in your Nmax calculations. In NVZs, there are mandatory closed spreading periods for high readily available N (RAN) organic materials (i.e. those which contain more than 30% of their total N content as RAN). Most liquid digestates contain a high percentage of their total N as RAN, with farm-based whole and separated liquor digestates typically containing between 65% and 90% respectively of their total N as RAN (Table 6.1). These liquids are subject to the closed spreading periods for high RAN materials stipulated in the NVZ Action Programme rules. Fibre digestates should always be tested to determine the RAN content, as it may exceed 30%, in which case they too would be subject to the closed spreading periods.

5.3 The Water Environment (Controlled Activities) (Scotland) Regulations (as amended)[14]

Controls exist under General Binding Rule 18 (GBR 18: The storage and application of fertiliser) within the Controlled Activities Regulations (CAR Regulations) that regulate the storage and land spreading of organic and manufactured fertilisers including digestates (SEPA, 2022).

Table 5.1 GBR 18 stipulates that organic fertiliser must not be applied to land that:

Is within 10 m of any river, burn, ditch, wetland, loch, transitional water or coastal water;	Is within 50 m of any spring that supplies water for human consumption or any well or borehole that is not capped to prevent water ingress;	Has an average soil depth of less than 40 m and overlies gravel or fissured rock, except where the application is for forestry operations;	Is frozen (except where the fertiliser is farmyard manure), waterlogged, or covered with snow; or	Is sloping, unless it is ensured that any run-off of fertiliser is intercepted (by means of a sufficient buffer zone or otherwise) to prevent it from entering any river, burn, ditch, wetland, loch, transitional water or coastal water towards which the land slopes.

The rules also state that fertiliser of any type should not be applied in excess of crop requirements and that equipment used for spreading must be maintained in a good state of repair. If fibre digestate is stored in a heap in field, it must be applied to land within 6 months of the commencement of the storage. Other requirements within GBR 18 are covered in the **practical guide to the CAR Regulations** (SEPA, 2022[4]).

The Controlled Activities Regulations (CAR) that cover slurry, silage and digestate storage and application have been revised and updated. The amendments came into force on January 1st 2022. These amendments directly impact the digestate market and all those working within this sector need to ensure that they read and understand the changes that have been made. **Farming Water Scotland** have highlighted and summarised some of the changes, what you need to know and the timing of when you need to act. Details can be found **here**[15].

From January 2023, there will be a requirement in Scotland for all non-waste, whole and separated liquor digestates to be stored in a liquid digestate storage system, slurry storage system or slurry bag. The base and walls must be impermeable, protected against corrosion, capable of withstanding loads, not situated within 10 m of any surface water, operationally maintained and must have drainage pipes with two lockable values. Similar controls already exist for waste digestates. Liquid digestate storage systems and slurry bags, which were constructed, or which were granted planning permission before 1 January 2022 have until 1 January 2024 to comply.

5.4 Animal By-Products Regulations[16]

Digestates, which have been derived (or partly derived) from animal by-products, which includes most food waste feedstocks, must have been processed in an animal-by-product approved facility and must only be applied to agricultural land in accordance with the Animal By-Products Regulations. You can find the current list of ABP-approved plants **here**. These EU regulations are implemented in Scotland by the **Animal By-Products (Enforcement) (Scotland) Regulations 2013 and the Animal By-Products (Miscellaneous Amendments) (Scotland) Regulations 2015**. There are grazing bans of defined length when digestates based partly or wholly on animal by-products are applied to pasture or to land used to grow forage crops:

- **The land cannot be used for grazing within two months of the application date for pigs; and**
- **three weeks for other farmed animals.**

Farmers who use animal by-products must keep records of the date, quantity and description of the materials applied, and the date on which pigs and other farmed animals first have access to the land after application.

5.5 Farm assurance schemes

Some of the farm assurance schemes have developed their own rules governing where and when organic materials including digestates can be used on their scheme members' land. For example:

Quality Meat Scotland requires that digestates made partly or wholly from wastes are either PAS110-certified or (for some types) have an authorisation from SEPA. In addition, physical contaminants should not exceed 8% of those permitted under PAS110, as per SEPA's additional requirements in Scotland. For further guidance please visit QMS Assurance website.[17]

Scottish Quality Crops (SQC) also allow PAS110-certified digestates, as well as use of digestate made on farms under their own SQC Approved Digestate Scheme. They do not permit the use of waste digestates. Further information and guidance can be found on the SQC website.

Check your farm quality assurance scheme rules before bringing digestate on to your farm and ensure that the way you plan to use it is compliant with your scheme rules.

5.6 Buyer acceptance

Some buyers have rules (which may be unwritten), which prohibit the use of certain types of digestate on crops that they buy, or even within the rotation. It is important to ensure that your product buyer is happy for you to use the type(s) of digestate that you plan to use in the manner that you plan to use them before you import them onto the farm.

5.7 Good Agricultural Practice

Digestates can present a considerable environmental risk if not stored and applied carefully. Best practice guidance for farmers on the storage, handling and application of organic fertilisers is provided in the **PEPFAA Code**[6]. A "Risk Assessment for Digestate Use Map" for the farm must be prepared and be made available to spreading contractors (Figure 5-1). The map must identify areas of high risk where field heaps must not be located and where digestate must not be spread. Information on creating such a map, other good practice guidance and regulations are available in the PEPFAA code and from **the Farming and Water Scotland website**.

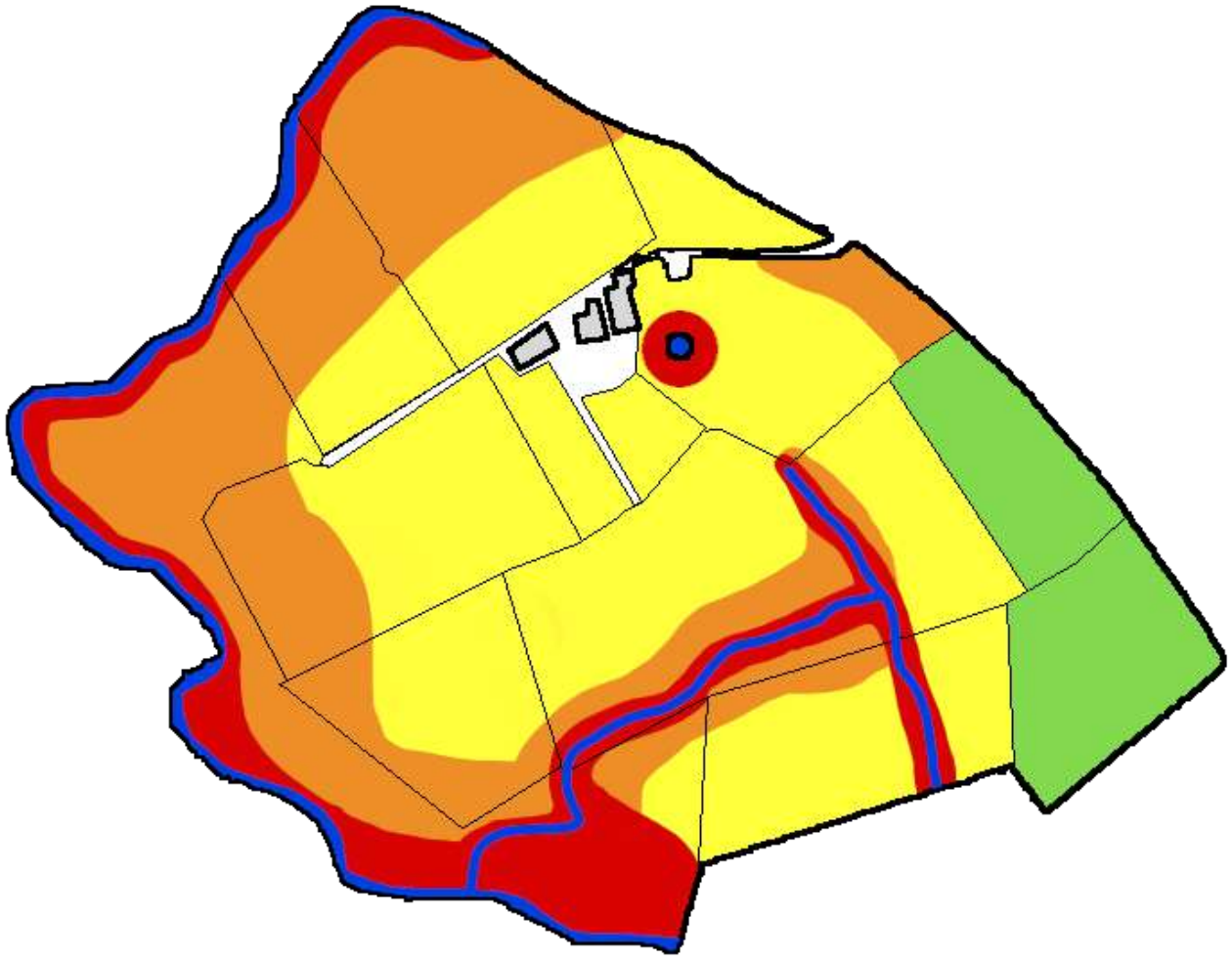

Figure 5 - 1 Example of Risk Assessment for Digestate Use Map for the farm.
© The 4 Point Plan (2003)[7]

6. Nutrient content of digestate types

The nutrient content and physical properties of digestates depend on both the feedstock from which they were made and the nature of the AD and post-AD processes. Digestate producers should be able to provide a recent with information on dry matter and nutrient content. When digestates are separated, most of the N and potassium (K) typically end up in the liquid and most of the phosphorus (P) ends up in the fibre. However, the extent to which that happens depends on the nature of the separation process.

A high percentage of the N present in whole and separated liquid digestates is typically present as ammonium-N. That and the small amount of nitrate-N present in digestates is termed readily-available-N (RAN). The percentage of the total N present as RAN in whole and separated liquid digestates is typically between around 65 and 90%, although values outside that range do occur. The typically high RAN content in whole and separated liquor digestates makes them excellent N fertilisers, however, there is also a high potential for N losses when they are applied inappropriately, and this means that they must be stored, handled and spread with great care. Fibre digestates tend to have lower RAN contents (around 10 to 24%). However, RAN contents of > 30% (which render them subject to NVZ closed periods) are possible.

Typical dry matter, RAN and nutrient contents of food-based and farm-based digestates are shown in Table 6.1. However, digestate properties can vary widely from the values shown and for this reason, it is always worthwhile to **test digestates** when using them on your farm. Total N and RAN content in whole and separated liquid digestates are particularly critical, given the importance of applying appropriate amounts of N to crops. These can vary throughout the year, as the balance of feedstocks changes and can also be affected by evaporation or rainfall ingress during outdoor storage of digestate in uncovered lagoons.

Table 6.1 Typical dry matter (DM) and nutrient contents of digestates[18]

Digestate type	DM[1] (%)	RAN[2] (%)	kg/t (solids) or kg/m³ (liquids) Total				
			N	P_2O_5	K_2O	SO_3	MgO
Food-based, whole	4.1	79	4.8	1.1	2.4	0.7	0.2
Food-based, separated liquor	3.8	89	4.5	1.0	2.8	1.0	0.2
Food-based, separated fibre	27	25	8.9	10.0	3.0	4.1	2.2
Farm-based, whole	5.5	78	3.6	1.7	4.4	0.8	0.6
Farm-based, separated liquor	3.0	89	1.9	0.6	2.5	0.1	0.4
Farm-based, separated fibre	24	25	5.6	4.7	6.0	2.1	1.8

[1]DM = dry matter; [2]RAN = readily available N

When digestates form a major part of the fertilisers regularly used on the farm, quarterly laboratory testing for major and secondary nutrients, dry matter and ammonium-N is recommended, to enable accurate nutrient budgeting.

It is also worth testing for organic matter content in fibre digestates, particularly where the soils to which the digestates are applied are deficient in organic matter and there is an aim to increase soil organic matter contents.

Where farmers are taking occasional deliveries of digestate, they should obtain the most recent set of results from the AD Plant and should encourage the plant manager to test their digestates at least **four times per year.**

Rapid, on-farm tests (such as Quantofix or Agros) are recommended to quantify the amount of ammonium-N present in whole and separated liquid digestates immediately prior to spreading.

The accuracy and value of such tests depends on obtaining a sample, which is genuinely representative of the whole. This means that digestate within a tank or lagoon should be thoroughly mixed prior to testing and removal for spreading. Further information can be found at the **Biofertiliser Certification Scheme Guidance**[3] page and **Technical Note (TN736): Optimising the application of livestock farmyard manures and slurries**[19].

7 How to calculate fertiliser replacement value of digestates

Whether using published values for the nutrient content of organic fertilisers or test results from the material you plan to use, the availability of the nutrients for crop uptake must be assessed before the fertiliser replacement value of an application can be calculated.

7.1 Nitrogen

The amount of N available to the crop following digestate application will depend on how much of the N applied is lost through nitrate leaching and ammonia emissions.

The amount of N leached as nitrate following land application is mainly related to the:

Application rate	Percentage RAN in the digestate	Amount of rainfall after application	Soil texture

- **As ammonium-N is rapidly converted in the soil to nitrate-N, applying N during the autumn or early winter period should be avoided, as over-winter rainfall is likely to be sufficient to wash a large proportion of this nitrate out of the soil before the crop can use it.**
- **Delaying applications until late winter or spring will reduce nitrate leaching and increase the efficient use of applied N. This is particularly important for whole and liquid digestates, which typically have a high RAN content.**

Research studies have shown that ammonia emissions from applications of whole and liquid digestate are usually greater than from cattle slurries. Emissions from applications of these digestates can be reduced by using precision application equipment such as band spreaders or shallow injectors. Such equipment allows digestate to be spread evenly, increasing the nutrient use efficiency.

The percentage of total N taken up by the crop following application of whole and separated liquid digestate is shown in Table 7.1.

Table 7.1 Percentage of total N taken up by crop following application of whole and separated liquid digestate (use the value in brackets for grassland, winter oilseed rape and brassicas)[18 a].

	August to October		February to April	Summer
% RAN	**Sands, sandy loams, shallow soils**	**All other soils**	**All soils**	**All soils, all crops**
< 50%	10(15)	15(30)	40[b]	40[b]
> 50%	10(15)	15(35)	50[c]	50[c]

a. Values have been simplified because the MANNER-algorithms in NPK and PLANET Scotland have not yet been updated with new data from the DC-Agri Project and detailed estimates of crop available N supply from contrasting digestate application methods and timings could not be provided.
b. Default value in NVZs of 40% applies regardless of the timing of the application.
c. Default value in NVZs of 50% applies regardless of the timing of the application.

As fibre digestates usually contain low RAN content (< 30%), they are not usually subject to the closed spreading periods in the NVZ Action programme rules. Although the amount of N taken up by crops following application of fiber digestates is relatively low, N contained in organic forms is broken down slowly to become potentially available for crop uptake over a period of months to years (Table 7.2).

Table 7.2 Percentage of total N taken up by crop following application of fibre digestates.

August to October		November to January		February to April	Summer
Sands, sandy loams, shallow soils	**All other soils**	**Sands, sandy loams, shallow soils**	**All other soils**	**All soils**	**Grassland**
10	10	15	15	20 (25[a])	20

a. Incorporation by ploughing within 24 hours after application.

The risk of causing water pollution by spreading stackable solid materials is lower than for liquids, however, surface run-off can still occur if heavy rain falls shortly after an application.

Surface application rates for fibre digestate should never exceed 50 t/ha, and liquids should never exceed 50 m^3/ha.

However, many farmers prefer to limit applications of whole and liquid digestate to no more than 30 t/ha (or even 20 t/ha) in a single application, recognising the risks associated with applying high RAN to both crop health and to the environment.

Repeat applications should not be made for a period of at least three weeks (or two weeks where a 20 t/ha application has been made). This is necessary to allow the crop to utilise the available nutrients and reduces risk of scorch. More frequent applications may smother herbage and increase the chances of leaching and run-off.

All applications should take account of the soil conditions and the amount of rain forecast. Fibre digestates are usually applied through side or rear discharge spreaders. The more advanced models can achieve a very even spread of material within each pass. Spreading machinery should be calibrated to accurately quantify application rates. Only by knowing the weight of material in the spreader, the nutrient content (in kg/t of fibre digestate), and the number of spreader loads applied per hectare will it be possible to gain an accurate understanding of the amount of nutrients applied.

Where fibre digestate is surface-applied, nitrogen losses (ammonia) can be minimised by the material as quickly as possible after spreading, ideally within six hours. Applications should be managed to avoid compaction or damage to soil structure, incorporation should be restricted to the top 30 cm of soil, and they should not take place when soil conditions are poor.

Whole and separated liquor digestates are best applied using precision spreaders such as shallow injectors or band spreaders (e.g. trailing hoses and shoes). These can reduce N losses and minimise crop contamination (compared with crops, which have been treated with surface-broadcast applications).

The application of odorous liquid digestates tends to cause fewer complaints where low emission application methods are used.

Modern band spreaders can be fitted with flow meters and control systems that accurately manage the application rate and provide accurate records of the amounts applied.

Liquid digestates are still sometimes applied using slurry tankers, with splash plate applicators (note that there are restrictions on the use of high trajectory splash plates in NVZs and that they will be banned in Scotland in 2023 (see below)).

It is currently possible to use splash plate slurry spreaders, providing that weather and soil conditions are suitable, and that the sensitivities of nearby communities are considered. However, high N losses can occur through ammonia volatilisation when using this type of machine. For that reason, **splash plate spreaders will be banned in Scotland from January 2023**, primarily to reduce the N losses associated with their use.

7.2 Phosphate and potash

For digestates, it is estimated that around 50% of P will be available to the crop following application. However, the amount of P that is taken up by that crop might differ, depending on the:

Placement of P in relation to the establishing crop roots	Root depth	P sorption capacity of the soil
Soil temperature	Crop type	Yield potential

These issues also apply to crop uptake of P from water-soluble P fertilisers. The P sorption capacity (PSC) of a soil refers to its capacity to bind with applied P, thus making that P temporarily unavailable for plant uptake. The PSC varies depending on soil chemistry, soil texture, pH and soil organic matter content (see **TN715–718**[2021,22,23] and SRUC **TN668**[24]). The applied P that is not taken up by the first crop will be released slowly over the crop rotation and will become available over a period of years.

The percentage of total P applied in the digestate, that is recommended to use in planning the balance of P crop requirement, is given in Table 7.3. Where crop responses to P are expected (e.g. where soils have very low or low P status); or where responsive crops (e.g. potatoes or vegetables) are grown on moderate P status soils, 50% of the total P content of the organic fertiliser should be used when calculating the P contribution. Where soil P status is at the target level (M–, M+ or H, depending on the crops grown in the rotation) or above (e.g. H or VH), 100% of the total P content of the digestate should be used in planning the balance that should be applied as manufactured P. Where crops are sown in cold soil conditions and slow crop establishment is expected, ensure that some soluble P fertiliser is applied at sowing.

Where soil P status is above target, take care to ensure that total P inputs do not exceed the amounts removed in crops during the rotation by checking that the concentration of extractable P in soil test results is not increasing over time. This will avoid the soil P status becoming high and will reduce the risk of P pollution to surface water.

Table 7.3 Percentage of total phosphorus (P) applied in digestate that should be used in calculating the balance of crop P requirement.

	Soil P status			
Crop type	**Very low (VL) and low (L)**	**Moderate (M-)**	**Moderate (M+)**	**High (H)**
Low responsive	50	100	100	100
High responsive	50	50	50	100

Around 90% of potassium (K) is in a soluble form in digestates, therefore, readily available for crop uptake. K, unlike P, moves freely in soil solution. It is recommended to subtract 90% of the total K in digestates from bagged fertiliser requirement where soil K status is below target and particularly important in K-responsive crops such as carrots, parsnips and beet. Where soil K status is at the target level (M- or M+), depending on the crops grown in the rotation) or above (e.g. H or VH), 100% of the total K content of the digestate should be used in planning the balance that should be applied as manufactured K.

7.3 Sulphur and magnesium

Recent research published in **AHDB (2017) "Nutrient Management Guide (RB209)"**[25] has quantified sulphur (S) supply from biosolids applications and it is appropriate to use the same advice for digestate applications.

- **For autumn applications, the % of total S applied, which is available for the following crop may be 10-20%.**
- **For spring applications, S availability is expected to be higher; and**
- **As a rule around 20% of the S in digestate will be available to the crop in the year of application.**

An understanding of the expected S uptake in different crops and yields is helpful, and data can be found in SRUC **TN685**[26]**.**

Magnesium (Mg) behaves in soil more like K than P. However, Mg moves less freely in soil solution than K does, with movement being reduced in low soil temperatures. Fibre digestates can supply useful quantities of Mg (around 20 to 40 kg/ha typical applications).

7.4 Effect of the bulk density of fibre digestates on application rates

Fibre digestates may have bulk densities ranging from around 200 to 700 kg/m^3 depending on feedstocks and processing method. Standard nutrient values are provided for fibre digestates, based on their typical fresh bulk density. Where standard values (rather than analysis of your own materials) are used, you should estimate whether the bulk density of your material is typical of its type.

If it is heavier (wetter) it is likely to have lower nutrient concentrations (and more water) per fresh tonne of material

If it is lighter (drier), it is likely to have higher nutrient concentrations (and less water) per fresh tonne of material.

You should adjust your application rates accordingly or calculate how your crop nutrient applications will differ if your own organic material has a widely different bulk density from the published average.

8. Financial value of digestates

Fertiliser prices have increased markedly in the past year and for this reason, the financial value of bulky organic materials, including digestates have increased too. AD plant managers selling digestates are seeing increased interest in their products, farmers are enquiring about purchasing digestates for the first time and those already using them are particularly keen to gain maximum value from the fertiliser nutrients within them.

Current convention in the UK is to put a financial value on all of the P and K present in bulky organic manures, and to value only the percentage of N, which is going to become available to crops, which is to a large extent dependent on when the digestate is applied (Section 7.1). Financial values are not typically put on the S, Mg or trace element content of digestates, or the organic matter content of fibre digestates, although most cropping systems will benefit from the presence of these things in organic materials, to some extent.

Table 8.1 shows the financial values of three different examples of digestate. A value is put on all the P and K present, and three scenarios are given for the value of N within the digestates, depending on different percentages of crop-available N. For fibre digestates, crop available N also depends on whether grass or another crop is being grown and on whether the material is ploughed down within 24 hours.

Table 8.1 Financial value of three example digestates.

Based on fertiliser prices of £1.87 /kg (N), £1.17 /kg (P_2O_5) and 90 p/kg (K_2O)[a].
Valuations are based on scenarios where Crop N availability from digestate in the year of application is 10, 20, 30 or 50%, but in practice, crop N availability might be anywhere between 10 and 50%[b] (FAS, 2019).
All the P and potash present are valued.

Digestate example	10%	20%	30%	50%	100%	100% digestate (£)	
Whole digestate (< 50% RAN)							
Total nutrient content (kg/m³)	4.8	4.8	4.8	4.8	1.5	3.4	
Crop-available nutrient (kg/m³)	0.5	N/A[c]	1.4	2.4	1.5	3.4	
Financial value of nutrients (£)	0.94	N/A	2.62	4.49	1.76	3.06	£5.76-£9.31
Separated liquor (< 50% RAN)							
Total nutrient content (kg/m³)	3.2	3.2	3.2	3.2	0.8	2.7	
Crop-available nutrient (kg/m³)	0.3	N/A[c]	0.96	1.6	0.8	2.7	
Financial value of nutrients (£)	0.56	N/A	1.80	2.99	0.94	2.43	£3.93-£6.36
Separated fibre							
Total nutrient content (kg/t)	8.0	8.0	8.0	8.0	6.0	4.5	
Crop-available nutrient (kg/t)	0.8	1.6	N/A[d]	N/A[d]	6.0	4.5	
Nutrients (£)	1.50	2.99	N/A	N/A	7.02	4.05	£12.57-£14.06

a. Fertiliser prices were obtained from the AHDB website (https://ahdb.org.uk/GB-fertiliser-prices) and were last updated in February 2022.
b. Financial value of digestate varies, mainly depending on fertiliser prices and on crop nitrogen availability. Crop N availability depends primarily on the time of year at which digestates are applied, but also to some extent on soil texture, soil depth, crop type, rainfall and method of application. See FAS Technical Note TN699, Planet Scotland (URL or reference) or Manner NPK (URL or reference) for details of how to estimate crop-available N.
c. No published scenarios exist where 20% of the N in whole or separated digestate is crop available.
d. Research has shown that a maximum of 20% of the N in fibre digestates is likely to become crop available when surface applied and not ploughed in within 24 hours.

The financial value of whole and separated liquid digestates varies greatly depending on the application time and method, with potential losses being higher the higher % RAN the digestate contains.

Crop-available N can be as little as 10% or as high as 50%.

The example for separated liquor digestate with < 50% RAN in Table 8.1 is valued at between £3.63 and £5.11/ m³. If that digestate was applied at 20 t/ha over a 10 ha field, then the value of digestate applications for that field, with 10 or 50% crop-available N, would be £726 or £1,022 respectively.

The financial impact of poor digestate application practices is greater where digestates contain > 50% RAN, because the N is more easily lost.

The financial value of separated fibre digestates does not vary greatly depending on the way they are applied (mainly because crop available N from fibre digestates is generally relatively low and because a higher percentage of their value comes from P and K, which are less easily lost from soils than N is).

Fertiliser prices are currently high. They will continue to fluctuate, but are likely to rise further in future years as energy prices rise and as the availability of virgin rock phosphate decreases. The value of alternatives to manufactured fertilisers, such as digestates, is therefore also likely to increase in future.

9. Case study: AD plant working with Mid Coul Farm

9.1 How it began

Mid Coul farm is a mainly organic farming business growing cereals, silage and vegetables covering over 1,200 ha of land in Inverness-shire. In 2012, Mid Coul farm began to seek an alternative and innovative business model that would help make better use of their grass and clover. Initial discussions looked at the prospect of installing an AD plant on the farm, for which they could grow feedstock themselves, whilst gaining income from the government renewable energy incentives available at the time. However, while discussions were taking place, a developer offered to build a larger plant and set up a contract with Mid Coul for them to supply energy crops as a feedstock. This offer was accepted and, in 2015, a 1 MW plant was commissioned. This plant is operated by Mid Coul farm staff, burns the gas in an engine and supplies electricity to the grid. Later, a grid connection to the gas network became available and a second larger (2.4 MW) plant was built and commissioned to supply gas to the SGN network.

9.2 How it works

Mid Coul grows around 65,000 t of grass and hybrid rye as feedstock for the two AD plants. Farmyard manure is also included in the feedstock mix. They have also recently started to source feedstock from local distilleries, which means they can reduce the amount of their own silage required. Mid Coul Farm is paid for the feedstock, dependent on the number of m^3 of methane produced and they receive all the digestate back for land spreading. This method of payment is beneficial to both parties: the farmer has a dedicated and predicable market for energy crops produced, a low-cost fertiliser to use on the land and the chance to operate a system, which is to a large extent "closed", with a much-reduced carbon footprint compared to the previous operating system. The AD plant operator has certainty of feedstock supply, a relatively consistent feedstock and a ready, local outlet for the digestate.

Mid Coul spread the digestate to land themselves using a precision spreader. The business now uses the digestate as a complete replacement to imported manufactured fertilisers and feel that they have seen great improvements to the quality of their land.

Mid Coul regularly test their digestate, so they know its nutrient content and can decide how to best apply it to their land, thus ensuring best practice. Because the digestate is made from feedstock grown on the farm and is spread only on that farm, it does not require PAS110 accreditation. Since the feedstocks used are crop residues, distillery co-products and manure, only registration under a Paragraph 51 exemption from SEPA is required.

9.3 Lessons learned

Over the past 10 years, Mid Coul has developed strong working partnerships with developers and they themselves have made significant investments in the AD sector. They have learnt the value of AD and digestates as part of their business. They have had to develop and adjust their working practices over the years to ensure that they can make and use digestate to best effect for their business. Their top tips for those starting out in the AD sector are:

Regularly test the digestate: you need to know what is in it so that you can apply appropriately.	Digestate is a valuable product and needs to be viewed as such.	You need to think logically about how to cope and move large quantities of digestate around.	You need to be able to store digestate so that you only apply it when the crop needs it and when weather conditions are right.
Bite the bullet and buy the best kit to spread it properly. Do not skimp on equipment or techniques.	Do not use splash-plate slurry spreaders. Use precision spreaders to get the full benefit from digestate.	Spreading digestate well is a slow process: you must allow staff sufficient time to do the job properly.	You need the correct equipment to make the best of the fertiliser nutrients and minimise nutrient losses.

9.4 Future plans

Mid Coul is always looking into more efficient ways to store and spread the digestate to make the most effective use of it. They are currently investing in modernising and increasing their storage facilities and have recently improved their spreading capability with a five-wheeled, low ground pressure, self-propelled precision spreader. A nurse tank at each end of the field and a field tanker will also be used going forward. Soon, they hope to invest in a NPK sensor to ensure that the digestate is spread homogenously to land.

Getting into the AD sector has not been cheap. However, through partnerships and investment, Mid Coul Farm has significantly reduced fertiliser costs and has seen increased crop yields over the past few years. The business recognises the considerable benefits that AD and digestates can bring to the farm, providing the digestate is regularly tested, its properties are well understood and the material is spread to land using best practice.

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Conclusions

The AD sector within Scotland is vibrant and evolving. As the cost of manufactured fertilisers increases, interest in using digestate is also increasing and land managers need to ensure that they understand it and how best to use it on their land. Ensuring that digestate is tested and applied appropriately to match crop demand for nutrients is key to using it safely, sustainably and to best effect on farms.

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