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Agricultural use of biosolids, composts, anaerobic digestates and other industrial organic fertilisers

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Summary

- **Organic fertilisers such as biosolids, composts, anaerobic digestates and industrial wastes can be useful and cost-effective crop nutrient sources that can improve soil fertility and quality.**
- **The nutrient value of applied organic fertilisers must be included in your fertiliser management plan to fully realise the financial benefit.**
- **Typical nutrient contents provided in this note include Scottish data but it is strongly advised that you TEST YOUR OWN compost and digestate or request it from the supplier.**
- **When organic fertilisers classed as wastes are intended for storage and use on your land then an application to SEPA must be made before they are imported.**
- **BSI PAS 100-accredited composts and BSI PAS 110-accredited digestate are not treated as wastes in Scotland, and can be applied to land without further regulation providing they are used in accordance with additional SEPA rules.**
- **This note explains how to use non-farm organic fertilisers to best effect and provides guidance on compliance with the relevant legislation.**

1. Introduction

Many organic fertilisers such as sewage sludge (biosolids), composts, anaerobic digestates and industrial wastes applied to agricultural land are valuable sources of plant nutrients. When appropriately done, the recycling to land of organic materials allows their nutrient value to be used for the benefit of crops and soils, and can in some cases provide significant savings on the cost of manufactured fertilisers. Regular applications of bulky organic materials can improve water-holding capacity, drought resistance and structural stability, as well as the biological activity of soils. The greatest benefits are likely to be observed on soils where organic matter levels are low. Organic materials should be spread in rotation on all suitable land throughout the farm where agricultural benefit is likely, rather than on land which is conveniently situated in relation to steadings or roads. Care should be taken not to cause soil compaction, which will have a detrimental effect on crop growth and health, and may increase the risk of surface run-off. To fully realise the financial value of imported organic fertilisers and to comply with legislation, it is essential that their nutrient value is included in your fertiliser management plan.

Changes in biosolids production technologies, in particular enhanced phosphate removal from waste water, and advanced chemical and thermal digestion processes may impact on the nutrient content of biosolids. In addition, the continued growth in the bio-energy sector has resulted in a significant increase in both digestate volumes and types as the range of feedstocks available increases. There is a continuing need to ensure that the figures for the nutrient content of organic fertilisers are up to date and representative of current practice at the farm gate. It is always advisable to request an analysis report on a regular basis when receiving any type of organic material for on farm use.

This technical note can be used along with MANNER-*NPK*, a software tool that provides an estimate of crop available NPK supply from organic manure (including imported, non-farm organic waste) applications (http://www.planet4farmers.co.uk/manner) and PLANET Scotland, a software tool designed for routine use by Scottish farmers and advisers to plan and manage nutrient use on individual fields (http://www.planet4farmers.co.uk).

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2. Nutrient and liming content of organic fertilisers

2.1 Nutrient content

The nutrient content and physical properties of organic fertilisers depends on the feedstock from which they were made and the treatment processes. The values presented in Table A are likely to be close to those obtained through testing the majority of these types of organic fertilisers, but some values are different from those provided in AHDB (2017) "Nutrient Management Guide (RB209)" as some materials are unique to Scottish conditions. It is always worthwhile having the nutrient content of representative samples determined, particularly where material from the same supplier is used regularly over time. Analysis is particularly important where the properties of the organic materials concerned are likely to vary widely from the average values in Table A. This is most likely with green/food compost, waste food products and anaerobic digestates. Scottish green/food composts may include a high proportion of fish wastes and the mean figures may mask a HUGE variation in compost nutrient contents. Regular testing is recommended, particularly when feedstocks change.

Several Scottish AD plants separate their digestate into liquor and fibre fractions. The variability between these digestate fractions can be considerable (due to differences in feedstock, process and post-processing technologies) and we recommend that such products should be tested individually. Where there is predictable variation in feedstock composition (as is the case with most farm-based AD plants), then testing should be done at least every two months for the first year in order to determine changes in nutrient content of digestate throughout the year. Regular testing makes financial sense as testing is relatively inexpensive in comparison to the cost of failing to make appropriate crop nutrient applications. Producers of PAS100 compost and PAS110 digestate should be able to supply a typical analysis of their product.

Nitrogen (N) is present in organic materials in two main forms:

- Readily available nitrogen (RAN) (i.e. ammonium-N, nitrate-N and uric acid-N) is the N that is potentially available for rapid crop uptake in the year of application.
- Organic-N is the N contained in organic forms which are broken down slowly to become potentially available for crop uptake over a period of months to years.

Additional micronutrient and heavy metal analyses are required depending on the source of the organic material. Analysis of copper and zinc and some other heavy metals are mandatory for biosolids applications to agricultural land and recommended for paper crumble sludge. Testing for copper, zinc and five other heavy metals is also mandatory PAS 100 and PAS 110 compost and digestates when they are produced from waste products. Analysis of copper and zinc are also recommended for distillery effluent and pot ale and mercury is often requested by SEPA. Further information on copper data are found at http://www.sruc.ac.uk/downloads/file/2224/tn657_management_of_copper_in_soils_for_cereals

2.2 Liming value

Several types of organic fertilisers including paper crumble, lime-stabilised biosolids and some composts and fibre digestates have a useful liming value. In some cases, where such organic fertilisers are used regularly, there is no longer need to apply lime, so costs can be saved. It is important, where materials with a high liming value are used regularly, that soil pH is monitored at least every 2 years in order to avoid raising soil pH above that desirable for the crops grown. The liming value of the waste should be expressed as a percentage of the liming value of calcium oxide (CaO) as this will enable you to calculate an appropriate rate using technical note *TN656: Soils information, texture and liming recommendations* http://www.sruc.ac.uk/tn656. Liming values may range from 2 to 15% CaO, but higher values have been reported in exceptional cases.

Table A. Typical dry matter (DM) and nutrient contents of organic fertilisers

Organic fertilisers	DM (%)	kg/t (solids) or kg/m³ (liquids/slurries) Total N	RAN*	Total P_2O_5	Total K_2O	Total SO_3	Total MgO
Biosolids, digested cake	25	11	1.6	11	0.6	8.2	1.6
Biosolids, thermally dried	95	40	2.0	55	2.0	23	6.0
Biosolids, thermally hydrolysed	30	10	2.0	10	0.6	3.5	1.5
Biosolids, lime stabilised	25	8.5	0.9	7	0.8	7.4	2.4
Compost, green	60	7.2	0.1	2.6	5.2	2.3	3.2
Compost, green/food	60	13.9	0.7	6.9	6.8	3.0	4.6
Food-based digestate, whole	4.1	4.8	3.8	1.1	2.4	0.7	0.2
Food-based digestate, separated liquor	3.8	4.5	4.0	1.0	2.8	1.0	0.2
Food-based digestate, separated fibre	27	8.9	2.2	10	3.0	4.1	2.2
Farm-based digestate, whole	5.5	3.6	2.8	1.7	4.4	0.8	0.6
Farm-based digestate, separated liquor	3.0	1.9	1.7	0.6	2.5	0.1	0.4
Farm-based digestate, separated fibre	24	5.6	1.4	4.7	6.0	2.1	1.8
Paper crumble, chemically/ physically treated	40	2.0	0.1	0.4	0.2	0.02	0.2
Paper crumble, biologically treated	30	7.5	0.8	3.8	0.4	0.02	0.3
Distillery pot ale	5	2.5	0.1	1.8	1.1	0.02	0.2
Distillery effluent/sludge	2.5	1.5	0.2	1.3	0.4	0.15	0.1
Brewery wash water	1.0	0.3	0.04	0.2	0.1	0.1	0.02

*RAN readily available nitrogen

3. Legislation relating to the use of organic fertilisers on agricultural land

3.1 Waste Management Licensing (Scotland) Regulations 2011 (WMLR)

When organic materials classified as wastes are imported on to the farm, then their application to land is regulated by SEPA. In order to spread organic wastes on land you must register for 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 in the completed Paragraph 7 form. The addition of total 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. Paragraph 7 exemptions are normally required for paper crumble, distillery pot ale, spent lees and other distillery effluents, brewery waste water, abattoir waste water, off-specification or waste composts and digestates.

Composts are made from the controlled biological decomposition (with oxygen) of either solely garden wastes (known as green composts) or a mixture of food and garden wastes (green/food composts). Composts certified to the BSI PAS 100 specification under the UK Compost Certification Scheme meet pre-defined quality criteria and are not classified as wastes in Scotland. They can be applied to land without further regulation, providing they are used within the terms of SEPA's guidance on "Regulation of Outputs from Composting Processes"
https://www.sepa.org.uk/media/219843/wst-g-050-regulation-of-outputs-from-composting-processes.pdf

Anaerobic digestion (AD) is a managed biological process in which biodegradable materials are broken down by naturally occurring micro-organisms in the absence of oxygen to produce a stabilised residue, commonly called "digestate". Some AD plants produce a single "whole" digestate product, whereas others separate the digestate into pumpable liquor and stackable fibre fractions. Typical inputs to an AD plant could include manure and slurry, vegetable waste and crops including specially grown energy crops), domestic and commercial food waste, green waste, waste animal feed, dairy washings, silage waste and effluent. If the inputs are wastes, then the process is controlled under either the Waste Management Licencing Regulations (WMLR) or the Pollution Prevention and Control (Scotland) Regulations 2012 (PPCR). If none of the inputs are wastes, e.g. they are specially grown energy crops such as maize, beet or rye, and then the process is not regulated under the WMLR. Digestates certified to the BSI PAS110 specification under the UK Biofertiliser Certification Scheme meet pre-defined quality criteria and are not classified as wastes in Scotland, providing they are applied to land under the terms of SEPA's position statement on the "Classification of Outputs from Anaerobic Digestion Processes"
http://www.sepa.org.uk/waste/waste_regulation/guidance_position_statements.aspx.

Regulatory regimes such as the NVZ regulations (Section 3.4) and the General Binding Rules (GBRs) from the Water Environment (Controlled Activities) (Scotland) Regulations 2011 (Section 3.6) apply to all organic fertilisers, whether they are classed as wastes or not.

3.2 Animal By-Products (Scotland) Regulations.

Organic materials which have been derived (or partly derived) from animal by-products must have been appropriately processed and must be applied to agricultural land in accordance with the original regulations Animal By-Products (Scotland) Regulations 2003 which are now out of date. The current EU Regulations are implemented by the Animal By-Products (Enforcement) (Scotland) Regulations 2013 (http://www.legislation.gov.uk/ssi/2013/307/pdfs/ssi_20130307_en.pdf) and the Animal By-Products (Miscellaneous Amendments) (Scotland) Regulations 2015 (http://www.legislation.gov.uk/ssi/2015/393/pdfs/ssi_20150393_en.pdf) Use of most food/green composts and many food-based digestates in agriculture will be subject to the Animal By-Products Regulations. In particular, pasture land cannot be used for grazing within 2 months (for pigs) and 3 weeks (for other farmed animals) of applying materials derived from animal by-products. 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.

3.3 The Sludge (Use in Agriculture) (Amendment) Regulations 1990.

Biosolids are not classified as waste. The application of biosolids to agricultural land is regulated by The Sludge (Use in Agriculture) (Amendment) Regulations 1990. The purpose of these regulations is to limit the build-up of heavy metals in soil and to restrict the planting, grazing and harvesting of certain crops following application. The regulations state that the sludge shall be used in such a way that account is taken of the nutrient needs of the plants and that the quality of the soil and of the surface and ground water is not impaired. Biosolids producers are required to analyse field soils and sludge prior to application and to maintain records of applications of all sludge to agricultural land. Prior to storing biosolids, SEPA must be notified through the registration of a Paragraph 8 waste management license exemption under WMLR. Clear guidance on the safe use of biosolids in agriculture and registration requirements are provided in the "Safe Sludge Matrix" (http://www.assuredproduce.co.uk/_code/common/item.asp?id=4033093) and from the SEPA website (http://www.sepa.org.uk/waste/waste_regulation/application_forms/exempt_activities/paragraph_8.aspx).

The Biosolids Assurance Scheme (BAS) Standard, which is based on regulations and best practice, is audited by a third-party Certification Body to demonstrate that Members of the Scheme are conforming to its requirements. The resulting BAS Certified Biosolids should provide reassurance to food chain stakeholders and the public that these biosolids are safely and sustainably recycled to agricultural land. Scheme Members e.g. Scottish Water and their approved contractors will arrange for soil testing and will provide soil and biosolids data to the farmer.

3.4 Nitrate vulnerable zones (NVZs)

In NVZs, the total quantity of nitrogen (N) applied in organic materials must not exceed 250 kg N/ha in any 12 month period. An exception has been made for compost provided it is not applied to any field where the application would result in more than 500 kg/ha of total N from organic manure (including compost) in any 24 month period. This excludes manure deposited by animals whilst grazing. In NVZs, there are mandatory closed spreading periods for high RAN organic materials (i.e. those which contain more than 30% of their total N content as RAN). Liquid digestates contain a high percentage of their total N as RAN, with farm-based whole and separated liquor digestates typically containing 65% and 70% respectively of their total N as RAN (Table A). These liquids are subject to the closed spreading periods for high RAN materials stipulated in the NVZ Action Programme rules. The separated fibre from digestate should be tested separately as its RAN content will vary depending on its source and can be 30% or higher and therefore subject to the closed spreading periods under the NVZ Action Programme rules. Further guidance on NVZ regulations is provided in Scottish Government guidance on NVZs (http://www.scotland.gov.uk/Topics/farmingrural/Agriculture/Environment/NVZintro).

3.5 Farm assurance schemes

Some of the farm assurance schemes have developed their own rules governing where and when organic materials including biosolids and digestates can be used on their scheme members' land. Check with your farm quality assurance schemes and your produce buyer before using organic materials.

3.6 General Binding Rules

The Controlled Activities Regulations (CAR) regulations stipulate a set of General Binding Rules (GBRs) that regulate the storage and land spreading of organic and manufactured fertilisers. The regulations apply to all forms of nutrients applied for agricultural purposes including wastes, composts and digestate.

GBR 18: The storage and application of fertiliser 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 cm 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. Also if dewatered digestate or dewatered sewage sludge is stored in a heap in field, it must be applied to land within 6 months of the commencement of the storage.

There are additional requirements within GBR 18 that have not been covered and further information is available from the links provided below.

It is recommended that a Risk Assessment for Manure and Slurry (RAMS) map is drawn up for the farm and made available to spreading contractors, as this is a simple way of helping to ensure compliance with these rules. Information on creating a RAMS map, other good practice guidance and regulations are available in the PEPFAA code (htpps://www.gov.scot/Publications/2005/03/20613/51366) and from the Farming and Water Scotland website (https://www.sruc.ac.uk/info/120603/farming_and_water_scotland).

4. Nutrient availability from spreading organic fertilisers

4.1 Amount of N taken up by the crop following application

Whether using typical values for the nutrient content of organic fertilisers or the results of analysis, the availability of the nutrients for crop uptake must be assessed before the fertiliser replacement value of an application can be calculated.

The amount of N taken up by the crop following 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, the readily available-N content (RAN), the amount of rainfall after application and 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 organic fertilisers with a high content of RAN.

Research studies have shown that ammonia emissions from applications of whole and liquid digestate are usually greater than from cattle slurries. Ammonia emissions from liquid digestate applications 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. Assessments of percentage of total N taken up by the crop following application of whole and separated liquor digestate are shown in Table B. These assessments have been simplified because the MANNER-NPK algorithms have not been updated with the new data from DC-Agri and detailed estimates of crop available N supply from contrasting digestate application methods and timings could not be provided.

Stackable organic fertilisers such as biosolids, composts, separated fibre digestates and paper crumble usually contain low RAN content and are not subject to the closed spreading periods in the NVZ Action programme rules. Although the amount of N taken up by the crop following application of these fertilisers is relatively low (Table C), N contained in organic forms are broken down slowly to become potentially available for crop uptake over a period of months to years.

Figure A. Digestate (separated liquid). Photo Anna Becvar, Earthcare Technical Ltd.

Figure B. Digestate (separated fibre). Photo Anna Becvar, Earthcare Technical Ltd.

Table B. Percentage of total N taken up by the crop following application of whole and separated liquor digestate (use the value in brackets for grassland, winter oilseed rape and brassicas)

August-October		February-April	Summer
Sands, sandy loams, shallow	All other soils	All soils	Grassland
10(15)	15(35)	55	55

Table C. Percentage of total N taken up by the crop following application of stackable organic fertilisers

	% of total N taken up by the following crop					
	August-October		November-January		Feb-April	Summer
	Sands, sandy loams, shallow	All other soils	Sands, sandy loams, shallow	All other soils	All soils	Grassland
Biosolids	5	10	10	15	15 (20*)	15
Compost, green	1	1	5	5	5	5
Compost, green/ food	10	10	15	15	15	15
Digestate, separated fibre	10	10	15	15	20 (25*)	20
Paper crumble	5	5	10	10	10	10

*incorporation by ploughing within 24 hours after application

The risk of causing water pollution by spreading stackable solid materials is lower than for liquids. Surface run-off can still occur if heavy rain falls shortly after an application. Surface application rates for solids should never exceed 50 t/ha, and liquids should never exceed 50 m^3/ha. Many farmers prefer to limit applications of whole and liquid digestate to no more than 30 t/ha in a single application, recognising the risks associated with applying high RAN liquids. Repeat applications should not be made for a period of at least 3 weeks. 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.

Solids are usually applied through side or rear discharge spreaders. The more advanced models are capable of achieving an even spread of material within each pass which can help maximise their nutrient value. Spreading machinery should be calibrated in order to accurately quantify manure application rates. The physical characteristics of the material (e.g. dry matter content, straw content, fresh or old) will affect spreader performance. Only by knowing the weight of material in the spreader, the nutrient content (in kg per tonne of fresh material), 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 organic fertilisers are surface applied, N losses (ammonia) can be minimised by ploughing the material down as quickly as possible after spreading. Applications should be managed to avoid compaction or damage to soil structure; incorporation should be restricted to the top 30 cm of soil, and it should not take place when soil conditions are poor.

Liquids are often applied using slurry tankers, with splash plate applicators (note that there are restrictions on the use of high trajectory splash plates in NVZs). This is acceptable, providing weather and soil conditions are suitable, and providing the sensitivities of nearby communities are considered, but elevated N losses can occur through ammonia volatilisation. Low emission techniques, including shallow injectors or the use of band spreaders (e.g. trailing hoses and shoes) can reduce N losses and minimise crop contamination (compared with crops which have been treated with surface-broadcast applications). The application of odorous liquids tends to cause fewer complaints where low emission application methods are used. Slurry spreaders can also be fitted with flow meters and control systems that accurately manage the application rate.

4.2 Amount of P and K taken up by the crop following application

Limited work has been done on the availability of P and K to crops from application of non-farm based organic fertilisers. For livestock manures typically between 50 and 60% of P will be available to the crop following application. However, the amount of P that is actually taken up by that crop will be lower and is determined by placement of P in relation to the establishing crop roots, root depth, P sorption capacity of the soil, soil temperature, crop type and yield potential. These issues also apply to uptake of P from water-soluble P fertilisers. The P sorption capacity of a soil refers to the differing capacity of soils to bind with applied P making it temporality unavailable for plant uptake and varies depending on soil chemistry, texture, pH and organic content of your soil (see SRUC TN668) (http://www.sruc.ac.uk/downloads/download/996/tn668_managing_soil_phosphorus_april_2015). The applied P that is not taken up by the first crop will be released slowly over the crop rotation and will mostly become available over a period of years.

Percentage of total P applied in the organic fertiliser that is recommended to use in planning the balance of P crop requirement is given in Table D. Where crop responses to P are expected (e.g. where soils have very low or low P status); or where responsive crops are grown on moderate P status (e.g. potatoes or vegetables), 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 organic fertiliser 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 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 the concentration of extractable P in soil test results are not increasing over time. This will avoid the soil P status reaching an unnecessarily high level and will reduce the risk of P pollution to surface water.

Table D. Percentage of total P applied in the organic fertiliser that should be used in planning the balance of P crop requirement.

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

Between 80 to 90% of K is in a soluble form in organic fertilisers and is readily available for crop uptake. Potassium, unlike phosphorus, fertiliser moves freely in soil solution. However, K content in biosolids, paper crumble and brewery wash water is low and no realistic saving can be made in K fertiliser. In contrast K content is higher in composts and digestates. It is recommended to subtract 80% of the total K in composts from bagged fertiliser requirement where soil K status is below target and particularly important in highly K-responsive crops like carrots, parsnips and beet irrespective of K soil status. It is recommended to subtract 90% of the total K in digestates from bagged fertiliser requirement where soil K status is below target.

4.3 Amount of S and Mg taken up by the crop following application

Recent research published in AHDB (2017) "Nutrient Management Guide (RB209)" has quantified S supply from biosolids applications. For autumn application the % total SO_3 available for the following crop may be 10-20% from biosolids. For spring applications S availability is expected to be higher and as a general rule around 20% of the SO_3 in biosolids will be available to the crop in the year of application. It is appropriate to use similar S availabilities in other organic fertilisers. An understanding of the expected S uptake in different crops and yields is helpful, and data can be found in SRUC TN685 (https://www.fas.scot/publications/tn685-sulphur-recommendations-crops/)

Magnesium behaves in soil more like K than P but moves less freely in soil solution than K, being reduced in colder soil temperatures. Stackable organic fertilisers can supply useful quantities of 20 to 30 kg/ha MgO (Table A) that replaces the Mg taken off by the crop. For most vegetable crops the recommendation is to apply 150 kg/ha MgO where the Mg soil status is very low (VL) and 100 kg/ha where the status is low (L). Use of organic fertilisers alone is unlikely to increase Mg soil status from VL and L to moderate (M).

4.4 Effect of bulk density on application rates

Solid materials may have bulk densities ranging from 400 to 800 kg/m^3. Standard nutrient values are provided for each solid organic material, based on its 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.

In laboratory analysis reports, P, K, Mg and S and K are sometimes expressed in terms of mg of the element (for example potassium) / kg dry matter (DM) or % of the element in the DM. It is important to first convert these results to kg/fresh tonne of the element (e.g. potassium). To do that, you will need to know the dry matter content of the organic material in question.

It is also important to note that fertiliser recommendations are expressed in terms of the oxides of elements (i.e. phosphate [or P_2O_5] rather than phosphorus; potash [K_2O] rather than potassium, magnesium oxide rather than magnesium and sulphur trioxide rather than sulphur. This is purely a convention, but it is important to understand its importance to ensure you are using these fertilisers efficiently.

In practice, the amount of phosphorus (in kg/fresh tonne) present in an organic fertiliser should be multiplied by 2.29 in order to calculate the amount of phosphate (P_2O_5) present. Similarly, the amount of potassium (in kg/fresh tonne) present in an organic fertiliser should be multiplied by 1.2 in order to calculate the amount of potash (K_2O) present. Similarly, the amount of S (in kg/fresh tonne) present in an organic fertiliser should be multiplied by 2.5 in order to calculate the amount of SO_3 present; the amount of Mg (in kg/fresh tonne) should be multiplied by 1.5 in order to calculate the amount of MgO present.

If in doubt about how to interpret the results of laboratory analysis, farmers are advised to seek help from advisors with experience in the use of organic fertilisers.

5. Worked examples

5.1. Understanding the value of green compost application

Table E shows fertiliser recommendations and potential and actual savings in fertiliser costs where 30 t/ha green compost was applied in autumn prior to growing a winter barley crop which followed a winter rape crop. The NPK analytical values used were taken from Tables A, B and D. The NPK recommendations were based on information from SRUC technical notes TN651 and TN633 for an expected yield of 7.5 t/ha winter barley grown for feed following a crop of winter oilseed rape. The soil was a sandy silt loam and the grain and straw were removed. The Nitrogen Residue Group following the winter rape crop was 2. The soil P status and K status were below target at low (L). The actual financial saving from the application of the green compost was £64/ha. Any P and K not used by the crop in the year of compost application will be available for crops in subsequent years. Residual N will be available for crops in subsequent years; for example up to 10% in year 2. Green/food composts will also leave residual nutrients in a similar way.

5.2. Understanding the value of farmed-based whole digestate application

Table F shows fertiliser recommendations and potential and actual savings in fertiliser costs where 30 m^3/ha farm-based whole digestate was applied in spring prior to growing a spring barley crop and ploughed in within 6 hours of application. The NPK analytical values used were from Tables A, C and D. The NPK recommendations were based on information from SRUC technical notes TN651 and TN633 for an expected yield of 6.5 t/ha spring barley grown for feed following a crop of winter barley. The soil was a sandy loam and the grain and straw were removed. The Nitrogen Residue Group following the winter barley crop was 1. The soil P status and K status were at the target of moderate (M-). The actual financial saving from the application of the farm-based whole digestate was £92/ha. In this example there were no residual P and K remaining for subsequent crops. It is unlikely that residual N will be available for crops in subsequent years.

Table E. Savings in fertiliser costs where 30t /ha green compost was applied in autumn prior to growing a winter barley crop.

	Nitrogen (N)	Phosphate (P_2O_5)	Potash (K_2O)	Financial (£/ha)
1. Estimated total NPK in green compost (kg/t)	7.2	2.6	5.2	
2. Estimated total NPK applied in 30 t/ha green compost (kg/ha)	216	78	156	
3. Availability of NPK from green compost used in planning the balance of NPK crop requirement (%)	1%	50%	80%	
4. Estimated NPK contribution from green compost (kg/ha)	2	39	125	
5. Total NPK requirement for winter barley (kg/ha)	185	63	78	
Cost of total NPK required (£)[1]	*99.90*	*38.43*	*35.10*	*173.43*
6. Manufactured NPK fertiliser required in addition to compost (i.e. item 5 minus item 4)	183	24	0	
Cost of manufactured NPK required (£)	98.82	14.64	0	113.46
7. *Actual savings in year 1 (i.e. items 5 minus 6)*	*1.08*	*27.45*	*35.10*	*63.63*

[1]Based on prices for N, phosphate and potash of 54, 61 and 45p/kg respectively (The Farm Management Handbook, 2017/18)

Table F. Savings in fertiliser costs where 30 m³/ha farm-based whole digestate was applied in spring prior to growing a spring barley crop.

	Nitrogen (N)	Phosphate (P_2O_5)	Potash (K_2O)	Financial (£/ha)
1. Estimated total NPK in whole digestate (kg/t)	3.6	1.7	4.4	
2. Estimated total NPK applied in 30 m³/ha whole digestate (kg/ha)	108	51	132	
3. Availability NPK from whole digestate used in planning the balance of NPK crop requirement (%)	55%	100%	100%	
4. Estimated NPK contribution from whole digestate (kg/ha)	59	51	77	
5. Total NPK requirement for spring barley (kg/ha)	145	56	77	
Cost of total NPK required (£)[1]	*78.3*	*34.16*	*34.65*	*147.11*
6. Manufactured NPK fertiliser required in addition to digestate (i.e. item 5 minus item 4)	86	5	0	
Cost of manufactured NPK required (£)	*46.4*	*3.05*	*0.0*	*49.49*
7. *Actual savings in year 1 (i.e. items 5 minus 6)*	*42.6*	*20.13*	*29.25*	*92.04*

[1]Based on prices for N, phosphate and potash of 54, 61 and 45p/kg respectively (The Farm Management Handbook, 2017/18)

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