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Optimising the application of bulky organic fertilisers

SUMMARY

- Livestock manures should be viewed as valuable resources rather than as waste products. They can bring significant benefits to soils and crops when used appropriately, and their use can result in considerable savings on purchased fertilisers.
- Bulky organic fertilisers, other than livestock manures, (for example: biosolids, distillery effluent, compost and digestate) can be useful and cost-effective crop nutrient sources that can also confer benefits to soil fertility. They can be particularly useful where livestock manures are unavailable or in short supply.
- The principles of nutrient supply and losses, and the need for livestock manure management planning are explained.
- This note provides information on the 'typical' chemical and physical properties of the main types of bulky organic fertilisers and explains how to use the materials to best effect, whilst ensuring compliance with the relevant legislation.

1. Introduction

Bulky organic fertilisers applied to agricultural land may be produced on the farm (for example: farmyard manures, slurries and poultry manures) or brought in from outside the farm (for example: biosolids, paper crumble, distillery effluent, food wastes, compost and digestate). These materials are valuable sources of organic matter, major and secondary plant nutrients. Many also contain useful quantities of trace elements. Careful recycling to land allows their nutrient value to be used for the benefit of crops and soils, and significant savings in the cost of purchased fertilisers can be made.

Livestock manures and other bulky organic fertilisers add useful amounts of organic matter to soils. Their use can improve water holding capacity, drought resistance and structural stability, as well as the biological activity of soils. These improvements are most likely to be seen where bulky organic fertilisers are used regularly, and the greatest benefits are likely to be observed on light and heavy soils where organic matter levels are low. Organic fertilisers 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 when applying bulky organic fertilisers not to cause soil compaction, which may have a detrimental effect on crop growth and health, and may increase the risk of surface run-off.

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 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). Modules include:

- Field-level nutrient planning and record keeping.
- An *Organic Manures Inventory and Storage Requirements* module which calculates monthly quantities and the nutrient content of farm manures, and the minimum slurry storage requirement as required for compliance with Nitrate Vulnerable Zone Action Programme (NVZ AP) rules.
- An Organic Manure Storage Capacity module which calculates the storage capacity of existing slurry and solid manure stores based on store dimensions.

- A Livestock Manure N Farm Limit module which calculates the whole-farm manure N capacity for derogated and un-derogated farms, and the current N loading for compliance with this NVZ AP rule
- An Nmax function that calculates the farm maximum N (Nmax) for individual crop types for compliance with this NVZ AP rule.
- A Farmgate Nutrient Balance that calculates the balance of nitrogen, phosphate and potash coming onto the farm (e.g. in feeds, manufactured and organic fertilisers) and those exported off the farm (e.g. in farm produce).

2. Legislation and guidance

Bulky organic fertilisers can present a considerable environmental risk if not stored and applied carefully. The Water Environment (Controlled Activities)(Scotland) Regulations 2005, make it an offence to allow or cause slurry, manure or effluent to directly enter a watercourse or field drain. Guidance for farmers on the storage, handling and application of organic fertilisers is provided in the PEPFAA Code (http://www.scotland.gov.uk/Resource/Doc/37428/0014235.pdf).

In NVZs the total quantity of nitrogen (N) applied in organic manures (other than compost) must not exceed 250 kg N/ha in any 12 month period. Compost shall not be applied to any field where the application would result in the total nitrogen contained in organic manure (including compost) applied to any field in any 24 month period exceeding a rate of 500 kg per hectare, excluding that deposited by animals whilst grazing. In some situations, lower application rates may be appropriate. For example, where the amount of crop available N would exceed the crop requirement. Further guidance on NVZ regulations is provided in this Technical Note and in Scottish Government guidance on NVZs (http://www.scotland.gov.uk/Topics/farmingrural/Agriculture/Environment/NVZintro). In some fields, particularly on intensive livestock farms, it may be necessary (or advisable) to limit organic manure applications in order to avoid excessive enrichment of soil phosphorus (P) levels.

The General Binding Rules (GBR) that apply to all farmers in Scotland also stipulate that fertilisers shall not be applied in excess of crop requirements and places legal restrictions on how and when they can be spread. Further guidance on GBR's and diffuse pollution regulations are available from the Scottish Environmental Protection Agency (SEPA) (www.sepa.org.uk/water/water_regulation/regimes/pollution_control/diffuse_pollution.aspx).

The GAEC (Good Agricultural and Environmental Condition) measures relating to the land application of livestock manures are outlined in the Scottish Government website (http://www.scotland.gov.uk/Publications/2005/12/0990918/09207).

Bulky organic fertilisers imported on to the farm are generally classified as wastes. Their application to land is therefore regulated by SEPA. In order to spread organic wastes on land you must register for a Paragraph 7 exemption licence. 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.

Sewage sludges (often called biosolids), are not classed as wastes. The application of sewage sludge to agricultural land is regulated by The Sludge (Use in Agriculture) (Amendment) Regulations 1990. The purpose of the Regulations is to control the build-up of heavy metals in soil and to restrict the planting, grazing and harvesting of certain crops following application. The Regulation states 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. These statutory controls must be complied with in order to be eligible for the Single Farm Payment. Sludge producers are required to analyse field soils and sludges prior to application and to maintain records of applications of all sludge to agricultural land. Prior to storing sewage sludge SEPA must be notified through the registration of a Paragraph 8 waste management exemption. This notification must include where the material will be stored, and if it is to be spread to non agricultural land. Clear guidance on the safe use of sewage sludge 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).

BSI PAS 100 accredited composts are not regarded as wastes in Scotland, and can be applied to land without further regulation. Anaerobic digestates are currently classed as wastes in Scotland unless they are compliant with BSI PAS 110 and SEPA's position statement on digestate use (http://www.sepa.org.uk/waste/waste_regulation/guidance__position_statements.aspx). Non-accredited digestates must be applied to farm land under waste management licence exemptions (Paragraph 7). Again, some of the UK farm assurance schemes are likely to develop their own rules governing where and when digestates can be used on their scheme members' land.

Bulky organic fertilisers 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 Animal By-Products (Scotland) Regulations 2003. 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. Management planning and characteristics of bulky organic fertilisers

Some of the farm assurance schemes have developed their own rules governing where and when bulky organic fertilisers can be used on their scheme members' land. Check with your farm quality assurance schemes and your produce buyer before using non-agricultural organic fertilisers. Use of these fertilisers may have commercial consequences for acceptability of produce to retailers and processors.

When planning livestock manure management systems, information is needed on the quantity and nutrient content of manures produced on a farm. Standard figures of N, P_2O_5 and K_2O outputs (ex housing and storage) by different categories of grazing livestock are given in Table A and non-grazing livestock in Table B. In NVZs, you should continue to calculate the N produced by livestock on your farm in accordance with the steps outlined in the Scottish Government Guidance for Farmers in Nitrate Vulnerable Zones (2008) (http://www.scotland.gov.uk/Topics/farmingrural/Agriculture/Environment/NVZintro).

Table A. Standard figures of N, P_2O_5 and K_2O produced by different categories of grazing livestock

Livestock type	Total N produced by 1 livestock type (kg/year)[1]	Total P_2O_5 produced by 1 livestock type (kg/year)	Total K_2O produced by 1 livestock type (kg/year)
1 Dairy cow (over 9000 litre milk yield)	115	52	92
1 Dairy cow (6000 to 9000 litre milk yield)	101	44	77
1 Dairy cow (up to 6000 litre milk yield)	77	34	61
1 Dairy heifer replacement, 13 months to first calf	61	25	58
1 Dairy heifer replacement, 3 to 13 months	29	10.3	24
1 Beef suckler cow[2] (over 500 kg)	83	31	66
1 Beef suckler cow[2] (up to 500 kg)	61	24	47
1 Steer / Heifer for slaughter, over 25 months	50	22	47
1 Steer / Heifer, 13 to 25 months	50	15.7	38
1 Steer / Heifer, 3 to 13 months	28	10	24
1 Bull beef, 3 months and over	54	8.8	38
1 Bull for breeding, over 25 months	48	22	38
1 Bull for breeding, 3 to 25 months	50	15.7	38
1 Calf, up to 3 months	1.4	0.77	2.6
1 Lamb (from 6 months up to 9 months)	0.5	0.07	1.3
1 Sheep (from 9 months old to first lambing, tupping or slaughter)[3]	0.7	0.38	2.6
1 Sheep up to 60 kg (inc. lamb to 6 months)	7.6	3.2	9.6
1 Sheep over 60 kg (inc. lamb to 6 months)	11.9	3.7	14.4
1 Goat	15	6.9	10.2
1 Breeding deer	15.2	6.4	12.4
1 Deer (other)	12	4.3	9.1
1 Horse	21	20	54

[1]Includes an allowance for N losses from livestock housing and manure storage
[2]Suckler cow: includes calf up to weaning age
[3] Assumes 6 months in this category

Table B. Standard figures of N, P_2O_5 and K_2O produced by different categories of non-grazing livestock (% occupancy in brackets)

Livestock type	%	Total N produced by 1 livestock type (kg/year)[1]	Total P_2O_5 produced by 1 livestock type (kg/year)	Total K_2O produced by 1 livestock type (kg/year)
1000 Laying Hens (caged) over 17 weeks	(97)	400	350	390
1000 Laying Hens (free range)[2] over 17 weeks	(97)	530	390	390
1000 Broiler Chickens (table)	(85)	330	220	340
1000 Laying Hens up to 17 weeks	(89)	210	150	120
1000 Broiler Chickens (Breeder) up to 25 weeks	(92)	290	260	270
1000 Broiler Chickens (Breeder) 25 weeks & over	(95)	700	520	720
1000 Turkeys (male)	(90)	1230	1020	950
1000 Turkeys (female)	(88)	910	740	690
1000 Ducks	(83)	750	730	230
1 Ostrich		1.4	6.8	10
1 Sow place (including litter up to 7 kg) fed on a diet supplemented with synthetic amino acids		16	13.5	14
1 Sow place (including litter up to 7 kg) fed on a diet without synthetic amino acids		18	13.5	14
1 Maiden gilt place 66kg and over	(80)	11.1	5.8	5.9
1 Breeding boar 66 kg to 150 kg		12	6.5	6.6
1 Breeding boar over 150 kg		17.5	10.2	11.4
1 Weaner place (7 to 13 kg)	(71)	1.0	0.34	1.2

Table B *continued*

Livestock type	%	Total N produced by 1 livestock type (kg/year)[1]	Total P_2O_5 produced by 1 livestock type (kg/year)	Total K_2O produced by 1 livestock type (kg/year)
1 Weaner place (13 to 31 kg)	(82)	4.2	1.8	2.1
1 Grower place (31 to 66 kg) (dry & liquid fed)	(88)	7.7	3.9	4.2
1 Finisher place (66 kg and over) (dry & liquid fed)	(88)	10.6	5.6	5.6

[1] Includes an allowance for N losses from livestock housing and manure storage
[2] Free range: 80% of excreta is deposited in the building (assumed)

Nutrient content of livestock manures and other bulky organic fertilisers

The nutrient content of manures applied to land depends on a number of factors, including the number and type of livestock, the diet and feeding system, the volume of dirty water and rainwater entering storage facilities, and the amount of bedding used. Typical livestock manure dry matter, total nutrient and readily available N contents are given in Table C, and for other bulky organic fertilisers in Table D.

Owing to farm specific feeding and manure handling practices, manures produced at a particular livestock unit may have a nutrient content that is consistently different from the values given in the tables. It is therefore worthwhile having the nutrient content of representative manure samples determined by analysis (see Section 4).

The nutrient content of other bulky organic fertilisers depends on the materials from which they were made and the processes through which they were treated. In some cases, for example distillery effluent and lime-stabilised biosolids, the degree of variation in chemical and physical properties between different batches from the same producer will be relatively small. The values presented in Table D are likely to be close to those obtained through testing the majority of these types of materials. However, for many other organic fertilisers, there is considerable variability in chemical and physical properties, depending on the input materials (or feedstocks) and the processes used to produce the material. It is always worthwhile having the nutrient content of representative samples determined, particularly where material from the same supplier is used regularly over time. However, analysis is particularly important where the properties of the organic fertiliser concerned are likely to vary widely from the average values in Table D. This is most likely with green/food compost, waste food products and digestate. Producers of PAS100 compost and PAS110 digestate should be able to supply a typical analysis of their product free of charge.

Table C. Typical dry matter (DM) and nutrient contents of livestock manures

Manure type	DM (%)	kg/t (solid manures) or kg/m³ (liquids/slurries)					
		Total N	Readily available N	Total P_2O_5	Total K_2O	Total SO_3	Total MgO
Cattle FYM – fresh	25	6.0	1.2	3.2	8.0	2.4	1.8
Cattle FYM – old	25	6.0	0.6	3.2	8.0	2.4	1.8
Pig FYM – fresh	25	7.0	1.8	6.0	8.0	3.4	1.8
Pig FYM – old	25	7.0	1.0	6.0	8.0	3.4	1.8
Sheep FYM – fresh	25	7.0	1.4	3.2	8.0	3.0	1.6
Sheep FYM – old	25	7.0	0.7	3.2	8.0	3.0	1.6
Duck FYM – fresh	25	6.5	1.6	5.5	7.5	2.6	1.2
Duck FYM – old	25	6.5	1.0	5.5	7.5	2.6	1.2
Layer manure	35	19	9.5	14	9.5	4.0	2.6
Broiler / Turkey litter	60	30	10.5	25	18	8.0	4.4
Horse FYM	30	7.0	0.7	5.0	6.0	*	*
Goat FYM	25	6.0	0.6	3.2	8.0	2.4	1.8
Cattle slurry	6	2.6	1.2	1.2	3.2	0.7	0.6
Pig slurry	4	3.6	2.5	1.8	2.4	1.0	0.7
Cattle slurry, strainer box liquid	1.5	1.5	0.8	0.3	2.2	*	*
Cattle slurry, weeping wall liquid	2	3.0	1.0	0.5	3.0	*	*
Cattle slurry, mechanically separated liquid	3	4.0	1.5	1.2	3.5	*	*
Cattle slurry, separated solids	20	4.0	1.0	2.0	4.0	*	*
Pig slurry, separated liquid	3	3.6	2.2	1.6	2.4	*	*
Pig slurry, separated solids	20	5.0	1.3	4.6	2.2	*	*
Dirty water	0.5	0.5	0.3	0.1	1.0	0.1	0.1

*data not available

Table D. Typical dry matter (DM) and nutrient contents of bulky organic fertilisers (other than livestock manures)

Manure type	DM (%)	kg/t (solid manures) or kg/m³ (liquids/slurries)					
		Total N	Readily available N	Total P_2O_5	Total K_2O	Total SO_3	Total MgO
Biosolids, liquid digested	4	2.0	0.8	3.0	0.1	1.0	0.3
Biosolids, digested cake	25	11	1.6	18	0.6	6.0	1.6
Biosolids, thermally dried	95	40	2.0	70	2.0	23	6.0
Biosolids, thermally hydrolysed	30	10	1.0	20	0.5	7.5	1.5
Biosolids, lime stabilised	40	8.5	0.9	26	0.8	8.5	2.4
Biosolids, composted	60	11	0.6	6.0	3.0	2.6	2.0
Green compost	60	7.5	0.1	3.0	5.5	2.6	3.4
Green / Food compost	60	11	0.6	3.8	8.0	3.4	3.4
Paper crumble, chemically / physically treated	40	2.0	0.2	0.4	0.2	0.6	1.4
Paper crumble, biologically treated	30	7.5	0.8	3.8	0.4	2.4	1.0
Waste food, general	5	1.6	0.1	0.7	0.2	*	*
Waste food, dairy	4	1.0	0.1	0.8	0.2	*	*
Waste food, soft drinks	4	0.3	<0.1	0.2	<0.1	*	*
Waste food, brewing	7	2.0	<0.1	0.8	0.2	*	*
Mushroom compost	35	6.0	0.2	5.0	9.0	*	*
Water treatment cake	25	2.4	0.1	3.4	0.4	5.5	0.8
Distillery pot ale	5	2.5	0.1	1.8	1.1	0.2	0.3
Distillery bioplant sludge	4	2.2	0.2	2.1	0.5	0.4	0.3
Distillery effluent	1.5	0.6	<0.1	0.5	0.2	0.1	0.1
Silage/whole crop effluent	6	2 - 4	0.8 – 1.6	1.5 - 2	3.5 - 7	*	0.4– 0.8
Digestate (whole), food based	4	5.0	4.0	0.5	2.0	0.4	0.1
Digestate (whole), pig slurry-based	2	3.6	2.9	1.8	2.4	1.0	0.7
Digestate (whole), cattle slurry-based	4	2.6	1.4	1.2	3.2	0.7	0.6
Digestate (separated liquor/fibre, food-based)	**	**	**	**	**	**	**

*no reliable representative data available at present

**Several Scottish AD plants that treat food waste 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 until more robust typical nutrient content data are available, we recommend that such products should be tested individually.

Availability of the nutrients for crop uptake

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. An understanding of the characteristics of the major plant nutrients in organic fertilisers will also help in planning applications that minimise diffuse pollution.

Nitrogen is present in bulky organic fertilisers in different forms:

- Readily available nitrogen (i.e. ammonium-N as measured by N meters, nitrate-N and uric acid-N) is the nitrogen that is potentially available for rapid crop uptake.
- Organic-N is the nitrogen contained in organic forms which are broken down slowly to become potentially available for crop uptake over a period of months to years.
- Crop available nitrogen is the readily available-N that remains available for the next crop following application. This also includes nitrogen released from organic forms.

Slurries and poultry manures are 'high' in readily available-N (typically in the range of 35-70% of total N, and more than 30% by definition in NVZs) compared with FYM which is 'low' in readily available-N (10-25% of total N). Nitrogen losses can occur following the land application of bulky organic fertiliser through ammonia volatilisation, nitrate leaching and de-nitrification. Ammonium-N can be volatilised to the atmosphere as ammonia gas following the land application of manures. Following conversion to nitrate-N, further losses may occur through nitrate leaching and de-nitrification (gaseous loss as nitrous oxide and nitrogen under warm and wet soil conditions). To make optimum use of the N content, organic fertilisers should be applied at times of maximum crop growth, generally during the late winter to summer period.

Around 40% of the readily available-N content of livestock manures is commonly lost via ammonia volatilisation following surface application to land. Ammonia loss and odour nuisance can be reduced by ensuring that manures are rapidly incorporated into soils (within 6 hours of application for slurries and 24 hours for solid manures). For livestock slurries, shallow injection and band spreading techniques (trailing shoe and trailing hose) are effective application methods that reduce ammonia emission (typically by 30-70%) compared with broadcast application. These application techniques also increase the number of spreading days, and cause less crop contamination than surface broadcast applications. The practices mentioned above will also increase the amount of N available for crop uptake. Ammonia losses are generally smaller from low dry matter slurries due to more rapid infiltration into the soil, compared with higher dry matter slurries, which remain on the soil/crop surface for longer leading to greater losses. Losses are also higher when slurries are applied to dry soils under warm weather conditions.

The amount of manure N leached as nitrate following land application is mainly related to the application rate, the readily available-N content and the amount of rainfall after application. As ammonium-N is rapidly converted in the soil to nitrate-N, manure applications 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 efficiency of utilisation of manure N. This is particularly important for manures with a high content of readily available-N. Values for the crop availability of N from different application timings and methods are given in Tables E to H.

In NVZs, there are mandatory closed spreading periods for high readily available-N manures (e.g. slurries, poultry manures) and default minimum N efficiency values (http://www.scotland.gov.uk/Topics/farmingrural/Agriculture/Environment/NVZintro.

Organic fertilisers are valuable sources of other nutrients as well as nitrogen, although not all of the total nutrient content will be available for the next crop. Nutrients which are not immediately available will mostly become available over a period of years and will usually be accounted for when soil analysis is carried out. The availability of manure phosphate to the next crop grown is lower than from water-soluble phosphate fertilisers. As a general rule, around 50% of the phosphate in pig and cattle slurries and other (non-agricultural) bulky organic fertilisers will become available to the crop in the year of application. Around 60% of the phosphate in solid animal manures will become available to the crop in the year of application.

Phosphorus is important with regard to water quality, because small increases in concentration can cause eutrophication (nutrient enrichment) of fresh waters. The effects of eutrophication include algal blooms, fish death, excessive weed growth, poor water clarity and loss of species diversity. The EU Water Framework Directive is focussing attention on the need to control eutrophication due to phosphorus movement from soils by requiring all surface waters to have good ecological and chemical status by 2015. Phosphorus moves from soil to water by:

- Surface run-off following recently spread organic fertilisers
- Erosion of soil particles containing phosphorus
- Particulate and soluble phosphorus in drain outflows

The risk of surface run-off of phosphorus, and also potassium, is reduced by avoiding surface applications of all organic fertilisers (solid or liquid) when soils are frozen, snow covered, waterlogged, or on steeply sloping ground adjacent to watercourses, or when there is a risk of heavy rainfall following application. Drawing up a risk assessment map is an important starting point for planning the application of organic fertilisers, and is mandatory in NVZs. Similar guidance is provided in "The 4 Point Plan, Straightforward Guidance for Livestock Farmers to Minimise Pollution and Benefit Your Business".

Most of the potash present in bulky organic fertilisers will become quickly available for crop uptake. Around 90% of the potash in bulky organic fertilisers will become available to the crop in the year of application, although potash availability from green composts may be rather lower in the first year (around 80%) and from dirty water, somewhat higher (estimated to be around 100%).

4. Practical aspects of using bulky organic fertilisers

Using organic and manufactured fertilisers together

If you apply organic manures, you should use the N efficiency values in Tables E to H to determine the percentage of the total N content that will become available to the crop. This available N value must be deducted from the N crop requirement in order to calculate the balance that needs be applied as manufactured N fertiliser.

Where crop responses to phosphate or potash are expected (e.g. where soils have very low or low P or K status for combinable crops and grassland) or where responsive crops are grown (e.g. potatoes or vegetables), the available phosphate and potash content of the manure should be used when calculating the nutrient contribution. Where soil status is at the target level or above (usually moderate), the total phosphate and potash content of the organic fertiliser should be used in planning the balance that should be applied as manufactured P and K. At high soil P status, take care to ensure that total phosphate inputs do not exceed the amounts removed in crops during the rotation. This will avoid the soil P status reaching an unnecessarily high level. It is important to manage manure phosphate and potash supply over the crop rotation. Organic fertilisers also supply useful quantities of sulphur and magnesium, but there is limited data on their availability for the next crop grown. Sulphur and magnesium inputs from manures should largely be regarded as contributing to the maintenance of soil reserves.

Liming value of bulky organic fertilisers

Several types of bulky organic fertilisers (in particular, paper crumble, lime-stabilised sewage sludge and some composts and digestates) have a useful liming value. In some cases, where such bulky fertilisers are used regularly, there is no longer a 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 and a laboratory analysis of their liming value is obtained. This should be expressed as a percentage of the liming value of calcium oxide (CaO) and will enable assessment of the likely impact of applying the material in question on soil pH.

Spreading of bulky organic fertilisers

The risk of causing water pollution by spreading solid manures is lower than for slurries. Surface run-off can still occur if heavy rain falls shortly after an application. Surface application rates for solid manures should never exceed 50 t/ha, and liquids including slurries should never exceed 50 m^3/ha. Lower rates should be used where soil and weather conditions are likely to increase the risks of pollution. Poultry manures should not be spread at rates exceeding 15 t/ha. 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. More frequent applications would smother herbage and saturate the soil, increasing the chances of leaching and run-off. All applications should take account of the soil conditions and the amount of rain forecast. Careful planning will help to minimise the risk of run off and entry into field drains.

Liquid materials 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. Newer application techniques, including shallow injectors or the use of band spreaders (e.g. trailing hoses and shoes) can result in less N losses and reduced crop contamination following treatment (compared with crops which have been treated with surface-broadcast slurries). The application of odorous liquid materials, such as slurries, tends to cause fewer complaints where the newer application methods are used. Slurry spreaders can also be fitted with flow metres and control systems that accurately manage the application rate.

Solid manures, composts and other ‘dry’, bulky materials are usually applied through side or rear discharge spreaders. The more expensive models are capable of achieving an even spread of material within each pass. Spreading machinery should be calibrated in order to gain a clear idea of how much bulky organic fertiliser is actually applied. 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 (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 nutrients applied.

Where bulky organic fertilisers are surface applied, nutrient losses (primarily ammonia) can be minimised by ploughing the material down as quickly as possible after spreading. Care must be taken when applying any bulky organic fertiliser 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.

Sampling for analysis

It is always advisable to have bulky organic fertilisers analysed prior to use, particularly where large volumes are being applied, or where similar materials are used regularly on the farm. The nutrient content of slurry can vary considerably within a store due to settlement and crusting. Similarly, the composition of solid manure in a heap can vary depending on the amount of bedding and losses of nutrients during storage. Batches of compost or digestate imported onto the farm may also vary considerably depending on the input materials and on the treatment methods used. Only by knowing the nutrient content of these materials can the amount of nutrients applied be optimised, fertiliser costs reduced and the potential for losses to the environment minimised.

Table E. Cattle and pig FYM – Percentage of total nitrogen available to next crop following manure applications

				% Total nitrogen available to the Following Crop					
				Autumn		Winter		Spring	Summer use on grassland
				August – October		November – January		February - April	
Manure Type	Incorporation time	Total N (kg/t)	Dry Matter %	Sands, Sandy Loams, Shallow[3]	All other soils	Sands, Sandy Loams, Shallow	All other soils	All Soils	All Soils
Cattle FYM (fresh[1] & old[2])	Over 24 hrs	6	25	5	10	10	10	10	10
Cattle FYM (fresh)	Within 24 hrs	6	25	5	10	10	10	15	N/A
Cattle FYM (old)	Within 24 hrs	6	25	5	10	10	10	10	N/A
Pig FYM (fresh & old)	Over 24 hrs	7	25	5	10	10	10	10	10
Pig FYM (fresh)	Within 24 hrs	7	25	5	10	10	10	15	N/A
Pig FYM (old)	Within 24 hrs	7	25	5	10	10	10	10	N/A

[1]Fresh FYM is manure that has been spread straight from the building.
[2]Old FYM is manure that has been stored for 3 months or more.
[3]In NVZs 10% must be used (http://www.scotland.gov.uk/Topics/farmingrural/Agriculture/Environment/NVZintro).
N/A Not applicable.

Table F. Poultry manure – Percentage of total nitrogen available to next crop following manure applications (use the value in brackets for grassland and winter oilseed rape cropping)

Manure Type	Incorporation time	Total N (kg/t)	Dry Matter %	% Total nitrogen available to the Following Crop					
				Autumn		Winter		Spring	Summer use on grassland
				August – October		November – January		February - April	
				Sands, Sandy Loams, Shallow[1]	All other soils	Sands Sandy Loams Shallow	All other soils	All Soils	All Soils
Layer manure	Over 24 hrs	19	35	10 (15)	25 (30)	25	25	35	35
Layer manure	Within 24 hrs	19	35	10 (15)	35 (40)	25	40	50	N/A
Broiler/Turkey litter	Over 24 hrs	30	60	10 (15)	25 (30)	20	25	30	30
Broiler/Turkey litter	Within 24 hrs	30	60	10 (15)	30 (35)	20	30	40	N/A

[1]In NVZs 20% must be used in 2010/11 and a minimum of 30% from 1st January 2012 (http://www.scotland.gov.uk/Topics/farmingrural/Agriculture/Environment/NVZintro).
N/A Not applicable.

The optimum sampling frequency for solid manures and slurries will vary depending on how manures are managed on the farm, but at least two samples per year are recommended, coinciding with the main spreading periods. It is important that sampling is carried out carefully and that representative samples are provided for analysis. The sample submitted should be made up of around ten sub-samples of around 1 kg each (at least five samples of 1 litre each in the case of liquid materials). These sub-samples should be taken from a range of positions within the tank, store or heap. Solid manure sub-samples should be spread out together on a clean dry tray or sheet (not used fertiliser sacks!), the lumps broken up and the whole sample well mixed. In the case of slurries the subsamples should be well mixed in a bucket or similar container. A representative sub-sample of the mixed material should be sent to the laboratory and a duplicate sample kept in a cool dry place until the results are received. Usually about 2 litres of slurry or about 2 kg of solid manure is required for testing, but farmers are advised to check the quantities required with their intended laboratory.

In NVZs, a specific protocol must be followed when sampling solid manures and slurries for determination of total N (see Booklet 9, Scottish Government Guidance for Farmers in Nitrate Vulnerable Zones, 2008, http://www.scotland.gov.uk/Publications/2008/12/12134339/11).

Samples of slurry and of other liquid organic fertilisers sent to a laboratory for analysis should be dispatched in clean screw-topped 2 litre plastic containers. Leave at least 5 cm of air space to allow the sample to be shaken in the laboratory. For solid manures and other solid organic fertilisers, use 500-gauge polythene bags and expel excess air from the bag before sealing. Clearly label the samples on the outside of the container or bag and dispatch them immediately or within a maximum of 7 days if kept in a refrigerator.

Producers of bulky organic fertilisers (other than livestock manures and slurries) are likely to have had their products analysed and can often provide information on the chemical and physical properties of the materials concerned. PAS100 compost producers and PAS 110 digestate producers will be able to provide potential users of their products with a representative analysis of the material supplied in terms of its heavy metal content and other properties.

Rapid on-farm kits (e.g. Agros, Quantofix) can reliably assess the ammonium-N content of slurries and other liquid organic materials and hydrometers can be used to assess dry matter content, but laboratory analysis is necessary for other determinations. Laboratory analyses should include dry matter (DM), total N, total P_2O_5, total K_2O, total SO_3, total MgO and ammonium-N (NH_4-N). Additionally, nitrate-N (NO_3-N) should be measured for well composted FYM and poultry manures and slurry that has been treated aerobically, and uric acid-N for poultry manures. It is desirable to test the neutralising value of materials that are likely to have a useful liming value (see Section 4, Liming value of bulky organic fertilisers).

Interpretation of analyses

Care must be taken when interpreting the results of laboratory analyses, as the results are often expressed in units that are not immediately useful. In order to determine how much bulky organic fertiliser to apply, total nutrients must be expressed as

Table G. Percentage of total nitrogen available to next crop following the application of cattle slurry and dirty water (use the value in brackets for grassland and winter oilseed rape cropping)

Manure Type	Incorporation time/method[1]	Total N (kg/t)	Dry Matter %	% Total nitrogen available to the Following Crop					
				Autumn		Winter		Spring	Summer use on grassland
				August – October		November – January		February - April	
				Sands, Sandy Loams, Shallow[2]	All other soils	Sands, Sandy Loams, Shallow	All other soils	All Soils	All Soils
Cattle slurry (surface applied)	Not incorporated	1.6	2	5 (10)	30 (35)	30	30	45	30
Cattle slurry (surface applied)	Not incorporated	2.6	6	5 (10)	25 (30)	25	25	35	25
Cattle slurry (surface applied)	Not incorporated	3.6	10	5 (10)	20 (25)	20	20	25	20
Cattle slurry (ploughed in)	Within 6 hrs	1.6	2	5 (10)	35 (40)	25	35	50	N/A
Cattle slurry (ploughed in)	Within 6 hrs	2.6	6	5 (10)	30 (35)	20	30	40	N/A
Cattle slurry (ploughed in)	Within 6 hrs	3.6	10	5 (10)	25 (30)	15	25	30	N/A
Cattle slurry (band spread)	Band spread	1.6	2	5 (10)	30 (35)	30	30	50	40
Cattle slurry (band spread)	Band spread	2.6	6	5 (10)	25 (30)	25	25	40	30
Cattle slurry (band spread)	Band spread	3.6	10	5 (10)	20 (25)	20	20	30	25
Cattle slurry (shallow injected)	Shallow-injected	1.6	2	5 (10)	30 (35)	35	35	55	45
Cattle slurry (shallow injected)	Shallow-injected	2.6	6	5 (10)	25 (30)	30	30	45	35
Cattle slurry (shallow injected)	Shallow-injected	3.6	10	5 (10)	20 (25)	25	25	35	30
Separated - strainer box	Select from above	1.5	1.5	Use the appropriate values for 2% dry matter cattle slurry					
Separated - weeping wall		2.0	3						
Separated - mechanical		3.0	4						
Dirty water	Not incorporated	0.5	0.5	10 (15)	35 (40)	35	35	50	30

[1]These values assume incorporation by ploughing. Cultivation using discs or tines is likely to be less effective in minimising ammonia losses and intermediate values of nitrogen availability should be used.
[2]In NVZs, nitrogen availability values in Scottish Government guidance must be used (http://www.scotland.gov.uk/Topics/farmingrural/Agriculture/Environment/NVZintro).

Table H. Percentage of total nitrogen available to next crop following pig slurry applications (use the value in brackets for grassland and winter oilseed rape cropping)

				% Total nitrogen available to the Following Crop					
				Autumn		Winter		Spring	Summer use on grassland
				August – October		November – January		February - April	
Manure Type	Incorporation time/ method[1]	Total N (kg/t)	Dry Matter %	Sands, Sandy Loams, Shallow[2]	All other soils	Sands Sandy Loams Shallow	All other soils	All Soils	All Soils
Pig slurry (surface applied)	Not incorporated	3.0	2	10 (15)	35 (40)	40	40	55	55
Pig slurry (surface applied)	Not incorporated	3.6	4	10 (15)	30 (35)	35	35	50	50
Pig slurry (surface applied)	Not incorporated	4.4	6	10 (15)	25 (30)	30	30	45	45
Pig slurry (ploughed in)	Within 6 hrs	3.0	2	10 (15)	45 (50)	35	50	65	N/A
Pig slurry (ploughed in)	Within 6 hrs	3.6	4	10 (15)	40 (45)	30	45	60	N/A
Pig slurry (ploughed in)	Within 6 hrs	4.4	6	10 (15)	40 (45)	25	40	55	N/A
Pig slurry (band spread)	Band spread	3.0	2	10 (15)	35 (40)	40	40	60	60
Pig slurry (band spread)	Band spread	3.6	4	10 (15)	35 (40)	35	35	55	55
Pig slurry (band spread)	Band spread	4.4	6	10 (15)	30 (35)	35	35	50	50
Pig slurry (shallow injected)	Shallow-injected	3.0	2	10 (15)	40 (45)	45	45	65	65
Pig slurry (shallow injected)	Shallow-injected	3.6	4	10 (15)	35 (40)	40	40	60	60
Pig slurry (shallow injected)	Shallow-injected	4.4	6	10 (15)	35 (40)	40	40	55	55
Mechanical separator	Select from above	3.6	3	Use the appropriate values for 2% dry matter pig slurry					

[1]These values assume incorporation by ploughing. Cultivation using discs or tines is likely to be less effective in minimising ammonia losses and intermediate values of nitrogen availability should be used.
[2]In NVZs, nitrogen availability values in Scottish Government guidance must be used (http://www.scotland.gov.uk/Topics/farmingrural/Agriculture/Environment/NVZintro).

the kilograms per fresh tonne of material (for solid materials) or kilograms per cubic metre (for liquid materials). In practice, laboratories often express results as mg/kg of nutrient in the dry matter (mg/kg DM) or percentage dry matter (% DM). In these cases, the % dry matter in the fresh material tested must be known in order to calculate the amount of each nutrient in the fresh material (as kg/t or kg/m^3).

Solid materials may have bulk densities ranging from 400 to 800 grams/litre. 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.

In laboratory analysis reports, phosphorus (P) and potassium (K) are usually expressed in terms of mg/kg DM or % DM. It is important to note that fertiliser recommendations are expressed on a phosphate (P_2O_5) and potash (K_2O) basis rather than for phosphorus and potassium. The amount of phosphorus-P (in kg/fresh tonne) present in a bulky organic fertiliser should therefore be multiplied by 2.29 in order to calculate the amount of phosphate (P_2O_5) present. Similarly, the amount of potassium-K (in kg/fresh tonne) present in a bulky organic fertiliser should be multiplied by 1.2 in order to calculate the amount of potash (K_2O) 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 bulky organic fertilisers.

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