Technical Note TN664

SRUC

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Management of cobalt in grassland soils.

- Soils have been mapped as having a "high", "moderate" or "low" predicted risk for cobalt (Co) deficiency. This predicted risk relates to the Co content of summer herbage inducing Co deficiency in ruminants.
- The likely influence of parent material, drainage characteristics and soil texture on Co availability is used in conjunction with total Co contents to allocate a risk category to soil associations.
- Soil associations are listed in order of the most common association mapping units for each risk level, along with the area that they cover.
- SAC Consultancy interpretative scales for extractable soil Co concentrations in topsoil are tabulated.
- Historical advisory soil extractable Co data measured as potentially deficient (VL or L status) were compared with risk predictions.
- Grassland treatment options are discussed.

1. Introduction

Cobalt (Co) deficiencies can affect the health and limit productivity of sheep and growing cattle due to its presence as a component of the structure of vitamin B12. Vitamin B12 is synthesised in the animals' rumen. Because other factors can come into play such as inhibitors in rumen and parasitic infections, there is only an approximate relationship between disease and Co intake.

Cobalt is essential for growth of rhizobium, the specific bacteria involved in legume nodulation and fixation of atmospheric nitrogen in legumes. Vitamin B12 which contains Co is synthesised by the rhizobium. Thus a deficiency in Co is shown in reduced Vitamin B12 production and lower nitrogen fixation.

Cobalt deficiency is widely distributed throughout Scotland but there can be large local variation in its distribution even within a farm. The soils of Scotland have developed from a range of complex geological parent materials that vary widely in composition. The soil association and series can indicate the probable degree of risk of Co deficiency. Cobalt deficiency can be corrected by soil and pasture treatments as well as oral dosing and supplementation to animal feed. This technical note will concentrate on management of cobalt in soils in relation to herbage quality.

Various site related factors will also be expected to influence any relationship that exists between the amount of extractable Co in soil and herbage Co content. Soil drainage modifies the availability of Co by influencing the rate of weathering of soil minerals and controlling the conditions of plant uptake. Poor natural drainage increases the concentration of extractable Co compared to soils of identical parent material developed under conditions of free drainage. Applying lime reduces the availability of Co.

In the current technical note soil data are used to develop a risk-based assessment of Co deficiency in herbage. Soils at risk of Co deficiency can be tested in order to establish the actual status in individual fields. The status in individual fields may have been altered by fertiliser application.

2. Predicted risk of cobalt deficiency

Soil associations have been categorised in order of the likely risk that they may sufficiently influence the Co content of summer herbage to induce Co deficiency in ruminants. The usual figure quoted as the minimum requirement in summer herbage is **0.08 mg Co/kg dry matte**r (DM). Most of the applied Co remains in the cultivated topsoil layer of well drained agricultural soils. Cobalt concentration in the subsoil (B horizon) is therefore expected to give the best indication of inherent risk of Co deficiency. The total Co in the B horizon has been grouped into soil associations, based on the proportion of fields likely to contain more or less than the minimum Co requirement for summer herbage. Soil associations have been designated as having "high", "moderate" or "low" predicted risk according to the criteria in Table A.

Table A. Total cobalt in the B horizon and risk of summer herbage containing less cobalt than required by ruminants.

Total Co in B horizon (mg/kg)	Risk level	Interpretation
<5	**High**	Soil association on which probably >50% of fields produce summer herbage containing <0.08 mg Co/kg DM
<10	**Moderate**	Soil association on which probably 10 to 50% of fields produce summer herbage containing <0.08 mg Co/kg DM
>10	**Low**	Soil association on which probably >90% of fields produce summer herbage containing >0.08 mg Co/kg DM

The distribution of the predicted risk for soil associations is mapped in Figure 1. Alluvial soils have not been designated a risk status as these soils are variable and Co risk depends on geological origin and texture as well as drainage. SAC Consultancy area office boundaries are mapped as an overlay in Figure 1.

Soil associations are listed in Table B in order of the most common association mapping units for each risk level, along with the area that they cover (as % of the mapped area of Scotland). High risk soils include organic soils, drifts derived from acid schists, granulites and granitic rocks (e.g. Arkaig, Aberlour and Countesswells), and drifts derived from greywackes and shales (e.g. Ettrick), and fluvioglacial sands and gravels (e.g. Corby).

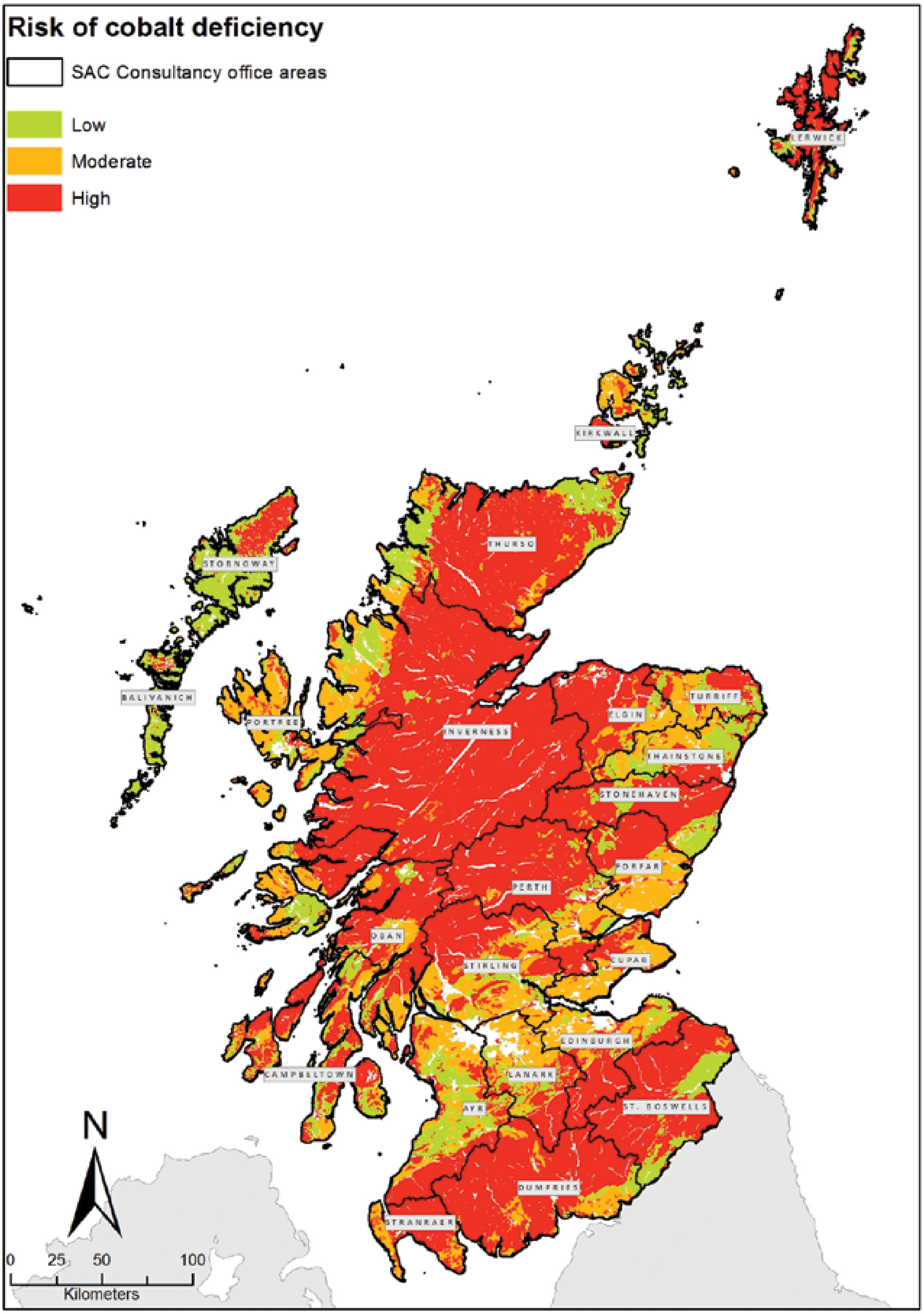
Soil texture and natural soil drainage modifies the availability of Co by influencing the rate of weathering of soil minerals and controlling the conditions of plant uptake. Poor natural drainage increases the concentration of extractable Co compared to soils of identical parent material developed under conditions of free drainage. Therefore the map should be seen as indicative, and local variation in drainage may push a soil into a higher or lower risk class. For example, the Thurso Association in Caithness is mapped as "low" risk as the association is dominated by the naturally poorly draining Thurso Series. In contrast, in Orkney the Thurso Association is mapped "moderate" risk as the association is dominated by the better draining Bilbster Series.

The James Hutton Institute, who holds the National Soils Database for Scotland, has created the Soil Information for Scottish Soils (SIFSS) website (http://sifss.hutton.ac.uk/SSKIB_Stats.php) which allows you to access information on your soils. SIFSS is also available as a free iPhone app for you to find out what soil type is in your area. The SIFSS system enables the user to select a soil 'map unit' by zooming in on a particular area (i.e. a field). This can be done by specifying a postcode, grid reference, or simply by zooming in using the interactive map. The user can then select a *soil association and a soil series* within this map unit. A soil association is a collection of soils of the same parent material typically found together in the landscape for an area. The association is divided into soil series according to the drainage status of soils in a particular area e.g. freely drained, imperfectly drained, poorly drained and very poorly drained. Each soil association bears the name of one of its series, usually that of the most characteristic series in the area in which the association was first described e.g. Thurso Association.

Table B. Soil associations with high, moderate or low risk of Co deficiency in summer herbage and association areas as % of the mapped area of Scotland.

High risk	% area	Moderate risk	% area	Low risk	% area
Organic soils	15.3	Rowanhill	3.1	Lochinver	2.9
Arkaig	12.4	Darleith	2.9	Tarves	1.9
Ettrick	8.5	Foudland	2.8	Thurso	1.0
Aberlour	7.4	Balrownie	1.7	Sorn/Humbie/Biel	0.6
Strichen	6.7	Torridon	1.4	Kintyre	0.5
Countesswells	4.7	Insch	0.6	Stirling/Duffus/Pow/ Carbrook	0.5
Corby	2.8	Forfar	0.5	Gourdie/Callandar/ Strathfinella	0.5
Sourhope	1.5	Rhins	0.5	Torosay	0.4
Durnhill	1.3	Mountboy	0.4	Kilmarnock	0.4
Hobkirk	0.7	Canonbie	0.4	Whitsome	0.4
Yarrow	0.5	Fraserburgh	0.4	Canisbay	0.4
Darvel	0.4	Berriedale	0.3	Glenalmond	0.3
Kippen	0.4	Carpow	0.2	Stonehaven	0.3
% of mapped area in Scotland	62.6		15.1		10.5

Figure 1. The risk of cobalt deficiency in summer herbage (high, moderate and low) by soil association



3. Diagnostic methods

3.1 Soil extraction. The soil extractant used by SAC Consultancy is 2.5% acetic acid with a soil:solution ratio of 1:20 (w/v). Although this gives some indication of Co status, interpretation is difficult as account must be taken of soil pH and drainage class, two important factors governing plant cobalt uptake. An explanation of soil drainage classification is given in the SIFSS website (http://sifss.hutton.ac.uk/SSKIB_Stats.php). Interpretative scales for extractable Co concentrations in soil are shown in Table C for mineral soils with up to about 15% organic matter and maintained at about pH 6.0.

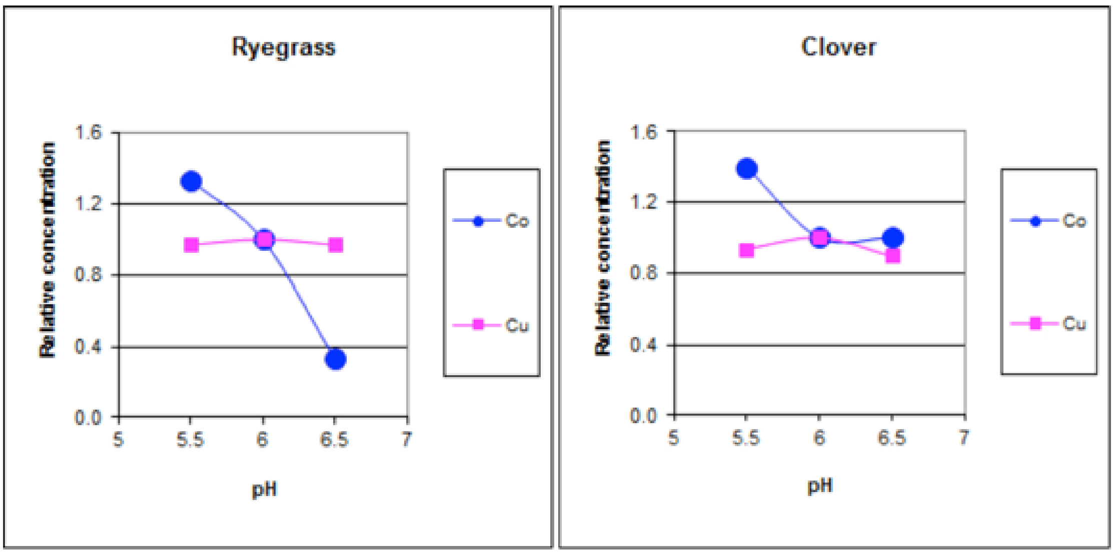
Table C. SAC Consultancy interpretative scales for extractable Co concentrations (mg/kg) in mineral soils with up to 15% organic matter and maintained at about pH 6.0.

	Soil drainage class			Probable Co concentration in leafy summer herbage
Co soil status	Free	Imperfect	Poor	
	mg/kg soil			mg/kg DM
Very low (VL)	<0.30	<0.20	<0.20	<0.045
Low (L)	0.30 - 0.74	0.20 – 0.65	0.20 – 0.45	0.045 – 0.065
Moderate (M)	0.75 – 1.0	0.66 – 0.94	0.46 – 0.85	0.066 – 0.094
High (H)	>1.0	>0.94	>0.85	>0.094

As the content of organic matter in the soil increases, the availability of Co also increases. For humose soils containing 15 to 35% organic matter extractable Co data for poor soil drainage class should be used or herbage Co could be determined in addition to soil Co. For peaty soils containing over 35% organic matter, Co should be determined in both herbage and soil. Organic soils contain less aluminium and for this reason can be maintained at lower pH values than for mineral soils for any given crop (see SRUC Technical Note TN656 http://www.sruc.ac.uk/downloads/download/722/tn656_soils_information_texture_and_liming).

Soil pH has a marked effect on reducing the availability to plants of soil Co in contrast to the effect on copper (Cu) availability. The relative concentration of Co and Cu in ryegrass and clover are shown in Figure 2 for different soil pH values. Soil analysis is particularly useful during the months when herbage samples can not be taken, and gives a rough indication of the Co status before the grazing animal shows adverse effects.

Figure 2. Effect of soil pH on relative concentrations of Co and Cu in ryegrass and clover.



3.2 Plant tissue tests. The interpretation of plant tissue Co levels is complicated by a number of factors:

- Different grass species contain different Co concentrations and clovers contain higher concentrations than grasses. A further complication is the selective grazing pattern of animals particularly sheep.
- Variation in the distribution and concentration of Co in different plant parts with leafy material containing more Co than stalks.
- Older plants contain less Co than younger plants, possibly as a reduction in the leafy area in relation to stems.
- The concentration of Co in the dry matter of hay, particularly hay made from grass-dominant herbage, will probably be lower by about 0.02 mg/kg dry matter than that in leafy summer herbage given in Table C.
- Soil contamination can result in highly elevated herbage Co values. Scales of interpretation are based on “clean” samples.

Chicory may contain higher concentrations of Co than perennial ryegrass and similar to white clover and may lead to higher vitamin B12 levels.

Plant analysis can be used to indicate the Co status of a pasture but it is best to monitor the situation over a grazing season rather than rely on one sample.

4. Historical advisory extractable Co levels in topsoil

A survey of SAC Consultancy advisory soil extractable Co data will improve our understanding of the extent and distribution of soils currently at risk of Co deficiency in grassland. Advisory data between 1996 and 2012 for 1,338 samples, mostly from grassland, are summarised in Table D into Co status. The distribution of Co status is shown in Figure 3 for the SAC Consultancy office areas with at least 30 soil samples.

The proportion of all samples measured as potentially deficient (VL or L status) was 80.4% using the interpretive scales for imperfect pedological drainage (Table D). This proportion of soil samples is in good agreement to the 76.7% of the total area mapped as high and moderate risk of Co deficiency (Figure 1). Reliability of the assessment of Co status based on soil testing would be improved if field LPIDs are supplied with soil samples so that soil association (1:250,000 map) and soil series (1:50,000 map) could be established.

Table D. Summary of advisory data for Co (% of the total number of samples).

	Very low (VL)*	Low (L)	Moderate (M)	High (H)
Co	17.5	62.9	13.0	6.6

*based upon using the interpretative scales for imperfect pedological drainage (<0.20, 0.20–0.65, >0.65–0.94, >0.94 mg/kg).

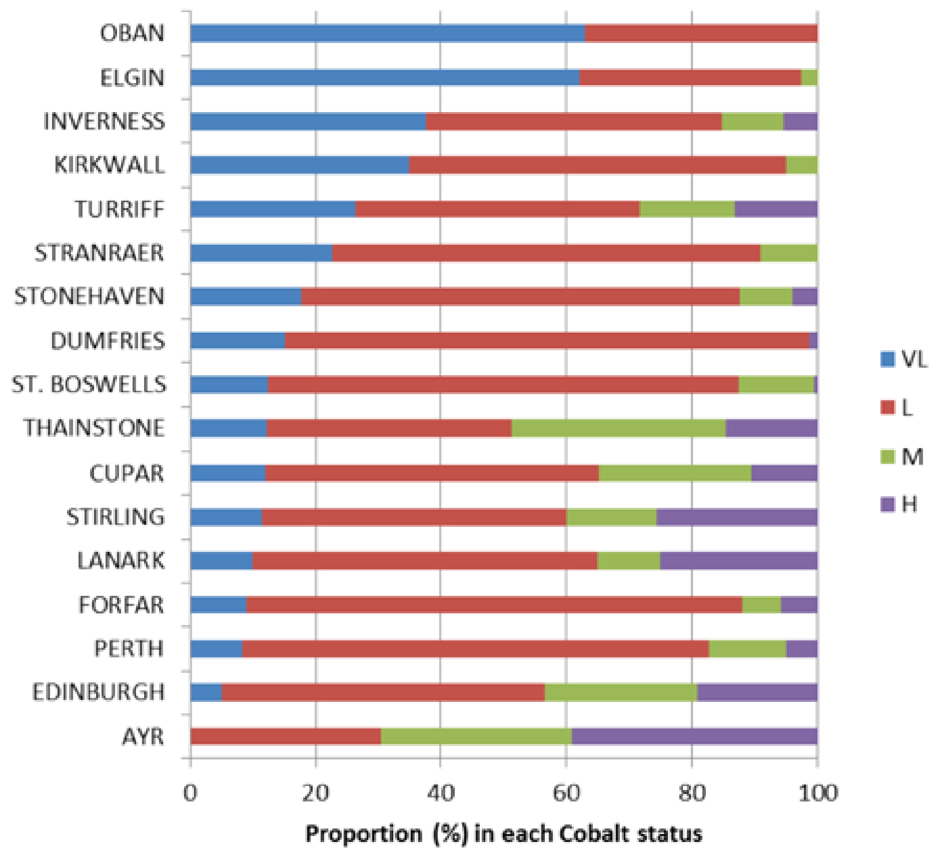


Figure 3. The distribution of Co status for SAC Consultancy offices.

5. Treatments

Most farms use intraruminal boluses containing cobalt or drenches containing cobalt due to problems obtaining hydrated cobalt sulphate to spread on pasture. Vitamin B12 injections are also available. Short acting vitamin B12 injections are authorised for use in the UK, while longer acting formulations require a special import licence

Scottish trials have shown improved serum vitamin B12 values and live weight gains in grazing ewes and lambs following application of 2-3 kg/ha of hydrated cobalt sulphate to pasture in early spring when grass height was still short, even though this treatment produced a similar or only slightly higher herbage Co concentration than the untreated ground in the second year.

The improvement in the Co status of the grazing animals in the second year was thought to be due to the ingestation of Co-enriched soil at the start of the grazing season. This effect should last for approximately 4 years following treatment. Sheep require access to treated pasture for only 50% of grazing time. This provides a basis for rotational treatment of pastures with one quarter of the grazing area treated every second year so that half the grazing area has an adequate cobalt supply. Cobalt should not be applied in close proximity to liming as hot spots in soil pH can lead to a reduction in Co availability.

In New Zealand, a mixed release rate Co composition of an acidulated phosphate together with a source of both slow release cobalt (carbonate) and quick release cobalt (sulphate) is used to treat soil deficient in cobalt.

Under the current EC Fertilisers Regulation, cobalt salts are authorized and different sources and forms of cobalt salts can be used in the production of EC fertilisers. However, the use of cobalt salts including sulphate and carbonate are under scrutiny as suspected carcinogens with a view to a possible use restriction under the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH). Because of health concerns over the use of cobalt salts suppliers of trace elements for livestock in the UK appear loath to market fertilisers containing Co salts. Suppliers prefer to market free access minerals containing Co for supplementing grass.

Livestock manures and other bulky organic manures can supply small amounts of Co. Table E shows typical Co concentrations in grams/tonne or m^3; and estimated amounts of Co that would be added to soil using an application rate based on maximum input from 250 kg total N/ha/annum). A high-yielding crop of 10t/ha of dry matter containing a typical Co concentration of 0.08 mg Co/kg DM will remove 0.8 grams Co/ha. More than this amount of Co can be supplied from cattle manure and biosolids; a similar amount from pig and layer manure; but not from distillery bioplant sludge (Table E). There is no data on the availability of Co for the next crop. Organic fertilisers are valuable sources of N, P and K although not all of the total nutrient content will be available for the next crop (see SRUC Technical Note TN650 on "Optimising the application of bulky organic fertilisers": http://www.sruc.ac.uk/download/downloads/id/1276/tn650). 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.

Table E. Typical NPK and Co contents of livestock manures and other bulky organic fertilisers and applications of Co per ha

Manure type	DM (%)	kg/t (solid manures) or kg/m^3 (liquids/slurries)			Grams/t or m^3	Grams Co/ha applied
		Total N	Total P_2O_5	Total K_2O	Total Co	
Cattle FYM	25	6.0	3.2	8.0	0.5	20
Cattle slurry	6	2.6	1.2	3.2	0.3	29
Pig FYM	25	7.0	6.0	8.0	0.2	7
Pig slurry	4	3.6	1.8	2.4	0.14	10
Layer manure	35	19	14	9.5	0.7	9
Broiler litter	60	30	25	18	0.6	5
Biosolids, digested cake	25	11	18	0.6	1.1	24
Biosolids, thermally dried	95	40	70	2.0	4.2	25
Biosolids, thermally hydrolysed	30	10	20	0.5	1.4	35
Distillery bioplant sludge	2.5	1.5	1.3	0.4	0.002	0.3

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