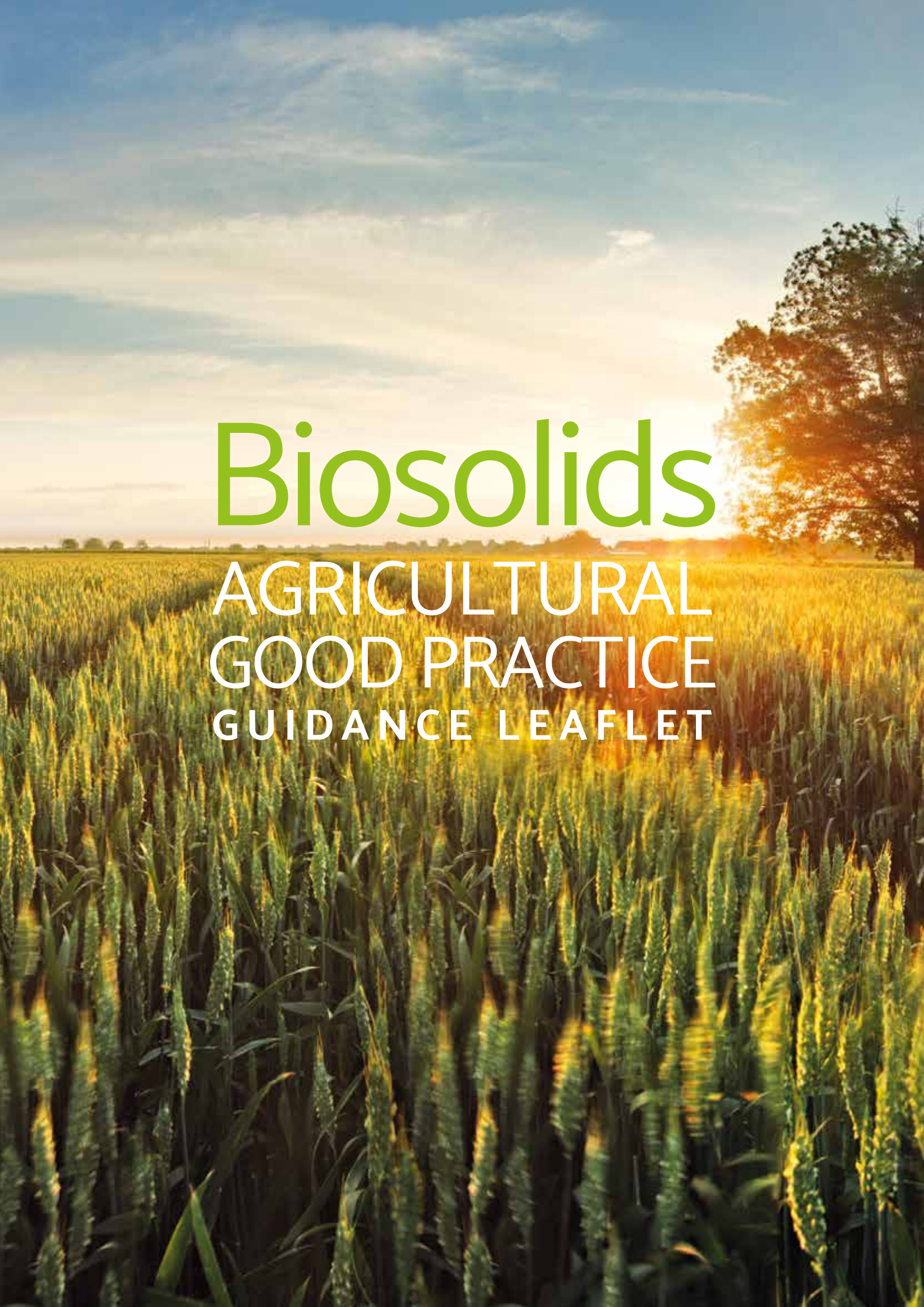


Biosolids

AGRICULTURAL GOOD PRACTICE

GUIDANCE LEAFLET

Introduction

This document defines biosolids and how best to use it sustainably on agricultural land to get best agronomic benefit. It outlines the legislation surrounding biosolids recycling to agricultural land and the available tools for calculating the nutrient benefits and financial value of biosolids. The guidance in this document will help you get the most from biosolids applications to agricultural land.

What are biosolids?

Biosolids is the term used to describe treated sewage sludge which is recycled to agricultural land (common practice for decades in the UK and many other countries).

In the UK, 3-4 million tonnes of biosolids are applied annually to agricultural land (Figure 1), representing around 75% of sewage sludge production. Around 150,000 hectares of agricultural land receive biosolids annually, with most applied to arable crop land.

Recycling biosolids to land is recognised by the European Union and UK Government as being the best practicable environmental option in most circumstances, as they provide valuable quantities of nutrients and stable organic matter to agricultural soils.

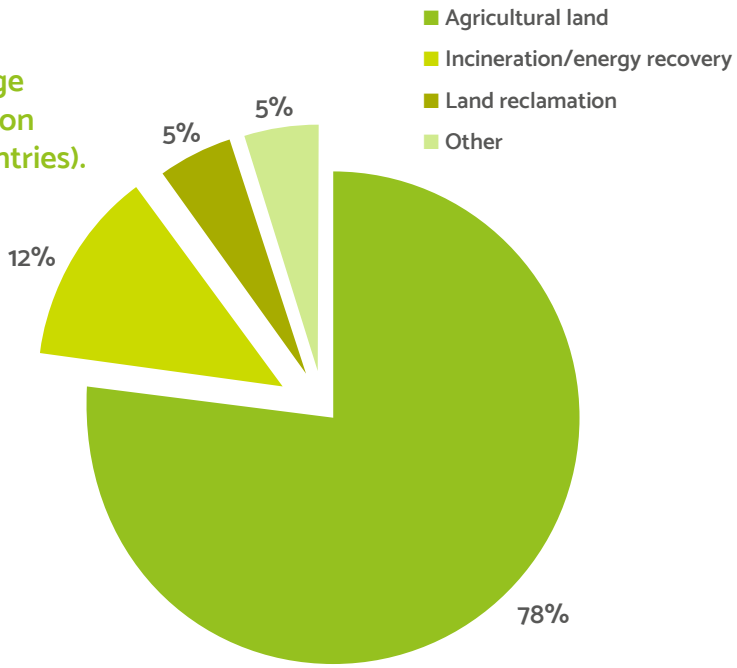
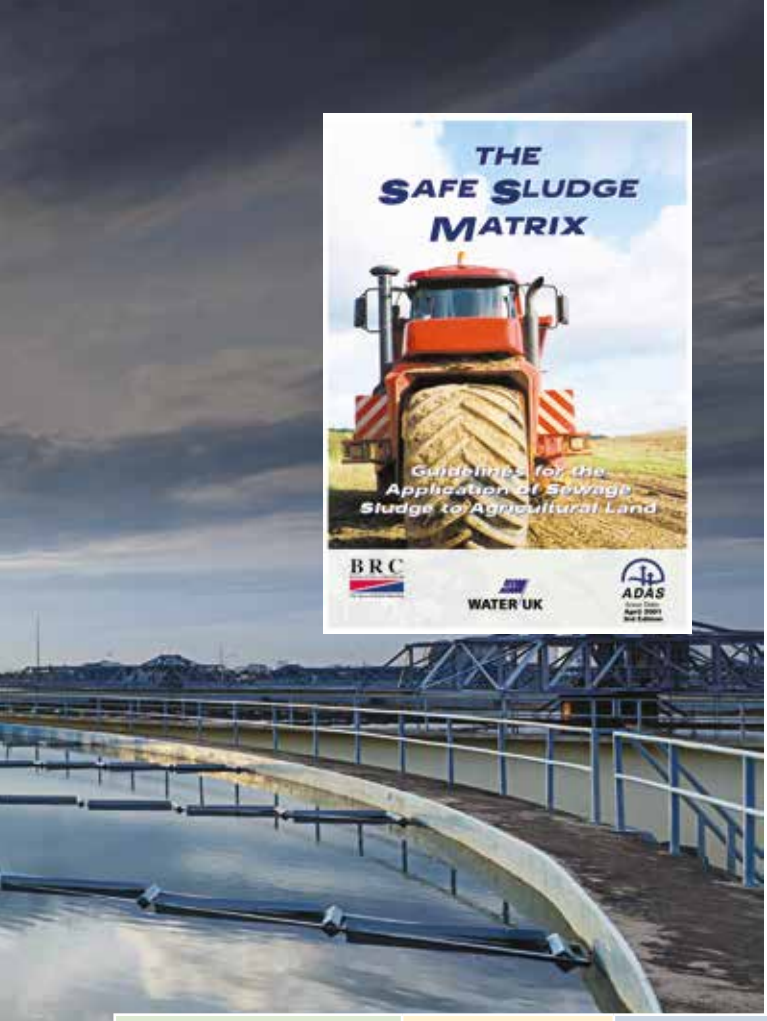


Figure 1. UK biosolids outlets



Sludge treatment

All sewage sludge is treated before recycling to agricultural land as biosolids, using approved procedures to ensure that hazards are analysed and critical control points (HACCP) are implemented to ensure a safe and quality product.

It must be treated and used in compliance with the Safe Sludge Matrix.

The Safe Sludge Matrix

The Safe Sludge Matrix represents an agreement between the Water Industry and the British Retail Consortium. It states minimum treatment standards (i.e. conventional or enhanced) that biosolids must meet before it can be recycled to agricultural land.

Additionally it states crop types that can be grown following biosolids application and harvest/grazing intervals to ensure food safety.

CROP GROUP	UNTREATED SLUDGES	CONVENTIONALLY TREATED SLUDGES	ENHANCED TREATED SLUDGES
FRUIT	✘	✘	✔ 10 month harvest interval applies
SALADS	✘	✘ (30 month harvest interval applies)	✔
VEGETABLES	✘	✘ (12 month harvest interval applies)	✔
HORTICULTURE	✘	✘	✔
COMBINABLE & ANIMAL FEED CROPS	✘	✔	✔
GRASS & FORAGE - GRAZED	✘	✘ (Deep injected or ploughed down only) ✔ 3 week no grazing and harvest interval applies (No grazing in season of application)	✔ ✔ 3 week no grazing and harvest interval applies
GRASS & FORAGE - HARVESTED	✘		

Fruit	Salad (e.g. ready to eat crops)	Vegetables	Horticulture	Combinable and animal feed crops	Grassland and forage	
					HARVESTED	GRAZED
Top Fruit (apples, pears, etc.) Stone Fruits (plums, cherries etc.) Soft fruit (currants and berries) Vines Hops Nuts	Lettuce Radish Onions Beans (including runner, broad and dwarf French) Vining Peas Mangetout Cabbage Cauliflower Calabrese/broccoli Courgettes Celery Red beet Carrots Herbs Asparagus Garlic Shallot Spinach Chicory Celeriac	Potatoes Leeks Sweetcorn Brussels sprouts Parsnips Swedes/turnips Marrows Pumpkins Squashes Rhubarb Artichokes	Soil based glasshouse and polythene tunnel production (including tomatoes, cucumbers, peppers etc.) Mushrooms Nursery stock and bulbs for export Basic nursery stock Seed potatoes for export Basic seed potatoes Basic seed production	Wheat Barley Oats Rye Triticale Filed peas Field beans Linseed/flax Oilseed rape Sugar beet Sunflower Borage	Maize silage Grass silage Haylage Herbage seeds	Grass Forage Swedes/turnips Fodder mangolds/ beet/kale Forage rye and Triticale Turf production

Recycling biosolids to agricultural land

There are a number of regulations and codes of practice that have to be followed when biosolids are recycled to agricultural land:

A brief overview of these is provided below:

- **The EU Sludge Directive** was implemented in the UK through **The Sludge (Use in Agriculture) Regulations** to protect human health and the environment. Maximum permissible soil heavy metal concentrations following biosolids applications and maximum annual heavy metal addition rates over a 10 year period are stipulated. Before biosolids can be applied to agricultural land, soil samples must be taken to ensure that heavy metal levels remain below maximum permissible concentrations. Heavy metal concentrations in present day biosolids products are much lower than in the past (Figure 2).

- **The Code of Practice for the Agricultural Use of Sewage Sludge** compliments The Sludge (Use in Agriculture) Regulations to ensure that the application of biosolids is in accordance with good agricultural practice and thereby protects human health and the wider environment.

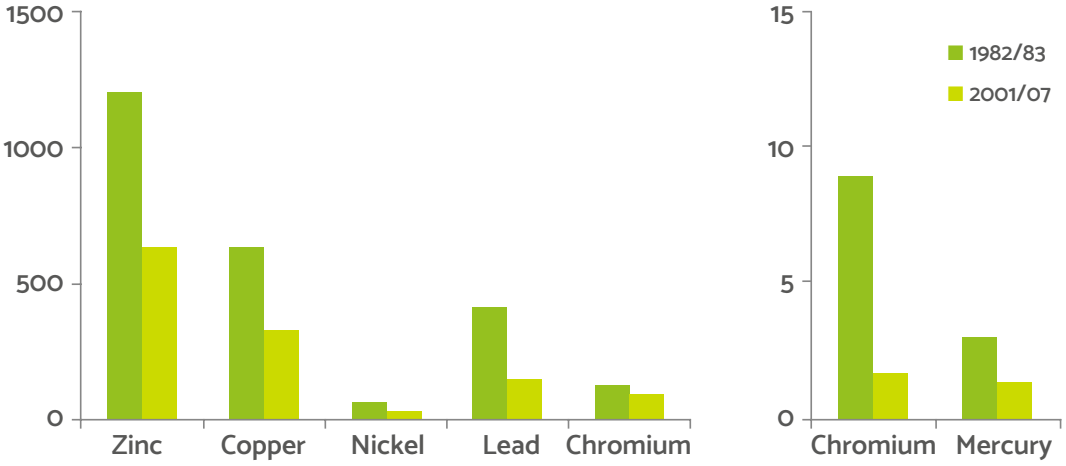


Figure 2. Heavy metal concentrations in biosolids over time (mg/kg dry solids)

The Biosolids Assurance Scheme

The purpose of the UK Biosolids Assurance Scheme (BAS) is to provide food chain and consumer reassurance that Certified Biosolids can be safely and sustainably recycled to agricultural land.

In consultation with food chain stakeholders the UK Water Industry has introduced the BAS that includes treatment of sludge (including source material controls), transport/ storage and application of biosolids.

The BAS brings together legislative and code of practice controls on biosolids recycling to agricultural land. Member organisations are audited by an independent third-party Certification Body to ensure that they conform with the Standard.

For more information visit: https://assuredbiosolids.co.uk

BAS
BIOSOLIDS ASSURANCE SCHEME

- **The EC Nitrates Directive** seeks to protect surface and ground waters from nitrate pollution. In the UK, water bodies that have 'elevated' nitrate levels have been designated as Nitrate Vulnerable Zones (NVZs). Within NVZs, a number of legally binding rules must be followed, which also apply to biosolids applications to agricultural land.

- **The Biosolids Nutrient Management Matrix**

  Clearly defines good practice in biosolids management. In particular, it provides a simple way of managing biosolids P inputs over crop rotations that is self-limiting (Table 1). The Matrix is used in conjunction with good nutrient management (e.g. RB209).

  The Matrix applies in England and Wales, in Scotland the rate and timing of biosolids applications must take account of the nutrient requirements of the crops as well as routinely analysing the soil for extractable P.

Table 1. Biosolids Nutrient Management Matrix

ADAS soil P Index	Maximum potential application of lime[a] stabilised biosolids	Maximum potential application of all other biosolids types
0/1/2	250kg/ha total N in any twelve month period	250kg/ha total N in any twelve month period
3	250 kg/ha total N in any twelve month period – application 1 year in 4 on sandy soils and 1 year in 2 on all other soils	250 kg/ha total N in any twelve month period – application 1 year in 2 on sandy soils[b]
4	250 kg/ha total N in any twelve month period – application 1 year in 5 on sandy soils and 1 year in 3 on all other soils	250 kg/ha total N in any twelve month period – application 1 year in 4 on sandy soils[c] and 1 year in 2 on all other soils
5 and above	No application	No application

a Lime addition rate >5% w/w on a dry solids basis.
b Composted biosolids can be applied annually and
c Can be applied 1 year in 2.

Notes:
- Soil extractable P analysis must be less than 5 years old (0-15 cm sampling depth on arable land; 0-7.5 cm on grassland)
- Soil types based on Cross Compliance soil categories.
- No biosolids applications directly in front of legumes (e.g. peas, beans), except for composted biosolids which are very low in readily available N.
- Septic tank sludge is not included within the scope of the Matrix.

Nutrient and soil quality benefits of biosolids

Biosolids provide valuable quantities of crop available nutrients that can be used to replace manufactured fertiliser additions and supply stable organic matter. Repeated applications will enhance soil quality and fertility. Most biosolids products are supplied with specific nutrient content data and other information.

Nitrogen

The total nitrogen (N) content of biosolids varies depending on the treatment process and resulting product type. Some N is present as readily available nitrogen (RAN) which is potentially available for immediate crop uptake following application to land. However, most of the N within biosolids is in an organic form and will slowly become crop available over time.

Typical total N and readily available N contents of the most commonly produced biosolids products are summarised in Table 2.

Following the application of biosolids to land, N can be lost, before it can be accessed by crops, through ammonia volatilisation to air; nitrate leaching losses to surface and ground waters; and denitrification to nitrous oxide and nitrogen gas.

To make best use of biosolids N, applications should be made at or before times of active crop growth – generally during the early spring and summer period. Where biosolids applications are made to bare soil/stubble they should be soil incorporated within 24 hours to minimise ammonia losses to air. The percentage of biosolids total N content that will be available for the next crop grown, in relation to product type, timing and application method, soil type and rainfall is summarised in Table 3.

Nitrogen will also be supplied to crops in the seasons following biosolids application. In the second year, digested cake has been shown to supply around 10% of the total N applied and 5% in the third and fourth years (Figure 3).

Recent research has shown that repeated biosolids applications can increase topsoil potentially mineralisable N concentrations, providing further evidence that the organic N in biosolids can be converted to plant available forms, contributing to crop N requirements and reduced mineral N fertiliser costs.

Table 2. Typical N contents of biosolids

Biosolids product	Dry matter (%)	Total N	Readily available N
		(kg/t fresh weight)	
Digested cake	25	11	1.6 (15%)
Thermally dried	95	40	2.0 (5%)
Lime stabilised	25	8.5	0.9 (11%)
Composted	40	11	0.6 (5%)

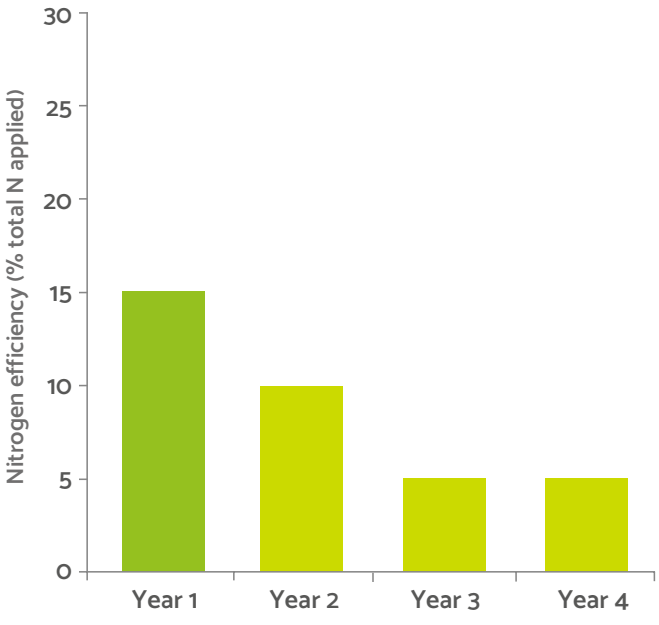


Figure 3. Nitrogen supply from a single biosolids application over four cropping seasons

Table 3. Percentage of total nitrogen available to next crop following biosolids applications (% of total N)

	Autumn[a] (Aug-Oct, 450 mm rainfall to end March)		Winter[a] (Nov-Jan, 250 mm rainfall to end March)		Spring[a] (Feb-Apr)	Summer[a] use on grassland
	Sandy/shallow[b]	Medium/heavy[b]	Sandy/shallow[b]	Medium/heavy[b]	All soils	All soils
Surface applied (i.e. not soil incorporated)						
Digested cake	10	15	15	15	15	15
Thermally dried	10	15	15	15	15	15
Lime stabilised	10	15	15	15	15	15
Composted	10	15	15	15	15	15
Soil incorporated 24 hours after application[c]						
Digested cake	10	15	15	15	20	N/A
Thermally dried	10	15	15	15	20	N/A
Lime stabilised	10	15	15	15	20	N/A
Composted	10	15	15	15	15	N/A

[use for grassland and winter oilseed rape cropping] N/A = Not applicable

a The nitrogen availability estimates assume 450 mm of rainfall (after autumn application) and 250 mm (after winter application) up to the end of soil drainage (end March). Where rainfall differs from these amounts, intermediate values of nitrogen availability should be used. For spring or summer applications, rainfall is not likely to cause movement of agronomically important amounts of nitrogen to below crop rooting depth.

b Sandy/shallow = light sand soils and shallow soils

Medium/heavy = medium, deep fertile silt and deep clay soils. Use this category for organic and peaty soils.

c The values assume incorporation by ploughing. Reduced cultivation using discs or tines is likely to be less effective in minimising ammonia losses and intermediate values of nitrogen availability should be used.

Phosphate

Phosphate (P_2O_5) is a finite non-renewable natural resource which is used in animal feed and fertiliser. Biosolids are a rich source of phosphate that can be recycled to land to replace manufactured phosphate fertiliser use; in the UK they supply about 35,000 tonnes of phosphate per annum with a potential financial value of over £25 million. Table 4 shows the typical phosphate contents of the most commonly produced biosolids products.

Typically, 50% of biosolids phosphate is available for crop uptake following application, with the remainder becoming available over future years.

However, the availability of phosphate may be lower if sewage has been treated using iron or aluminium salts to enhance the removal of phosphorus (P) from wastewater.

Repeated biosolids additions to 'low' P status soils will build up soil P reserves. Where the soil is at or above the target soil P status and a crop response is not expected the total phosphate content of the biosolids should be used in nutrient planning. Where the soil P status is in the range ADAS P Index 2-4, a rotational management approach to phosphate additions is recommended to make best use of phosphate inputs.

Table 4. Typical phosphate (P_2O_5) contents of biosolids

Biosolids product	Dry matter (%)	Total phosphate
		(kg/t fresh weight)
Digested cake	25	11
Thermally dried	95	55
Lime stabilised	25	7.0
Composted	40	10

Recent improvements in air quality have greatly reduced atmospheric sulphur deposition

Potash, magnesium and sulphur

Biosolids contain small amounts of potash which are typically 90% available to following crops. Magnesium is also present and should largely be regarded as contributing to the maintenance of soil reserves.

Recent improvements in air quality have greatly reduced atmospheric sulphur deposition and as a result sulphur deficiency is becoming increasingly common in arable (e.g. oilseed rape, cereals) and grassland crops. Recent research has shown that 10-20% of the total sulphur in biosolids is available to the next crop grown following autumn application (25% for grassland and winter oilseed rape) and 35% following spring application.

Typical biosolids potash, magnesium and sulphur contents are summarised in Table 5.

Trace elements

Biosolids supply trace elements that can be useful in supporting crop growth and in animal nutrition (e.g. copper, boron, cobalt, selenium and iodine). Around 5% of soils where cereals are grown in England and Wales, and 30% in Scotland are estimated to be copper deficient.

Table 5. Typical potash, magnesium and sulphur contents of biosolids

Biosolids product	Dry matter (%)*	Total potash (K_2O)	Total sulphur (SO_3)	Total magnesium (MgO)
		(kg/t fresh weight)		
Digested cake	25	0.6	8.2	1.6
Thermally dried	95	2.0	23	6.0
Lime stabilised	25	0.8	7.4	2.4
Composted	40	3.0	6.1	2.0

Soil organic matter benefits

Organic matter is a vital component of healthy and productive soils. Low organic matter soils are more vulnerable to compaction and structural damage, which can result in poor crop growth and yields. Biosolids are a good source of stable organic matter. Based on an application of 250 kg total N/ha (the maximum field N rate permitted in NVZs), a typical digested biosolids cake application will supply 3-4 t/ha of organic matter. The maintenance and enhancement of soil organic matter is a cross compliance requirement of the Basic Payment Scheme.

Soil quality benefits

Organic matter additions to agricultural soils provide many long-term benefits including; improved soil structure and workability, increased biological activity and increased water holding capacity. Notably, organic matter can hold up to 20 times its weight in water and can therefore directly affect soil water retention properties and, indirectly, soil structure.

Recent research has shown that organic matter inputs from repeated biosolids applications increase the plant available water capacity of soils, which improves the ability of crops to withstand periods of drought and can decrease the need for irrigation water, particularly on drought prone soils.

For example, where potatoes are grown the increased water capacity would translate into a yield increase of 3 t/ha, worth around £240/ha (based on 2018 prices) in increased crop output values at current prices. The study also showed that repeated biosolids applications can increase soil water infiltration rates, thereby improving topsoil drainage properties, and reducing the risks of surface water run-off (and hence flooding) and soil erosion.

The number and weight of earthworms has been found to approximately double where biosolids were applied (Figure 4). Earthworms have a major influence on soil quality, breaking down organic material, improving soil structure and allowing water and oxygen to move through the soil. Biosolids can play an important role in improving soil quality by promoting earthworm numbers.

Liming value

Lime stabilised biosolids have value as a liming material (neutralising value typically in the range 2-6% per tonne fresh weight) that can balance the acidifying effects of atmospheric deposition and fertiliser N use.

Effects on food quality

Research has found that where breadmaking quality wheat was grown, biosolids applications significantly increased grain sulphur concentrations, which has been shown to be related to improved bread quality (i.e. loaf volume).

There was no negative effect of biosolids applications on the taste or texture of bread produced from wheat, or on the quality and taste of the beer produced from barley, grown at sites with repeated biosolids applications.

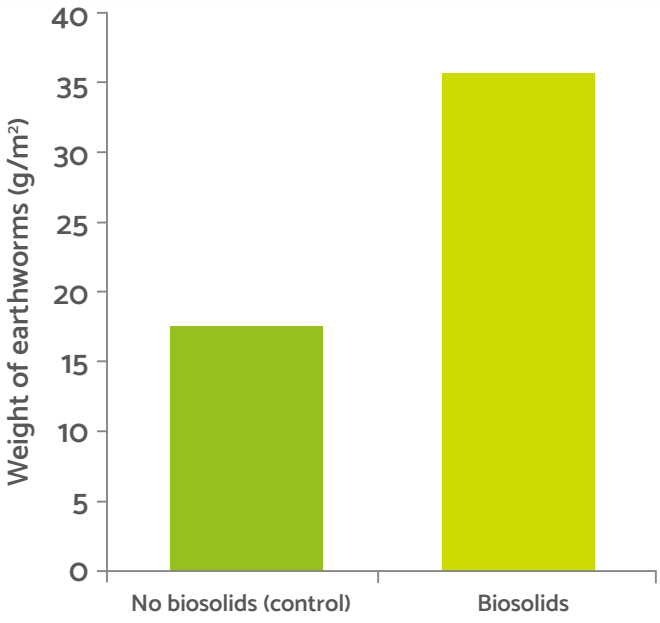


Figure 4. Weight of earthworms

Value of biosolids

Fertiliser replacement value of biosolids

Biosolids are a valuable source of major crop available nutrients (nitrogen, phosphorus, potash and sulphur), which can be used to replace manufactured fertiliser additions. Typical biosolids applications have a value of well over £200/ha (£80/acre) (based on 2018 prices); see examples in Tables 6, 7 and 8. Additional financial value will be supplied from other major nutrients (e.g. magnesium) and trace elements (e.g. copper) are applied, together with the benefits to soil quality obtained from applying stable organic matter.

The weight of spreading equipment can cause compaction when soils are 'wet', so it is important to apply biosolids when soil conditions are appropriate. To make best use of biosolids there is a need to develop a strong working relationship between producer and farmer users.

Carbon reduction benefits of biosolids use

Replacing the use of manufactured fertiliser with biosolids will reduce a farm's carbon footprint by around 20 kg CO^2/tonne of digested cake applied, or around 0.4 tonnes of CO^2e/hectare at a typical digested cake application rate of 20 t/ha.

Integrating biosolids and manufactured fertiliser use

Decision support tools have been developed to help farmers and advisers make best use of the nutrients in organic materials (including biosolids). MANNER-NPK and PLANET predict the fertiliser N replacement value of field applied biosolids, taking into account biosolids analysis data, soil type, application timing and technique, ammonia volatilisation, nitrate leaching and denitrification losses, and mineralisation of organic-N.

Integrating biosolids within a farm's nutrient management policy should aim to maximise (as far as practically possible) the nutrients supplied by the biosolids. Failure to do so not only wastes money because of unnecessary fertiliser use, but can reduce crop yields and quality (e.g. lodging in cereals, poor fermentation in grass silage, low sugar levels in beet) and cause environmental pollution.

The key steps are:

1. Identify the fields and crops that will benefit most from biosolids application (e.g. fields with a low P status, low in organic matter). Take into account accessibility and likely soil conditions at the time of application, and the application equipment available.
2. Where practically possible, apply biosolids in the early autumn ahead of crops with an autumn N requirement (e.g. oilseed rape) and soil incorporate within 24 hours on bare soil/stubble, or apply in early spring/summer. Calculate the quantity of total and crop available nutrients (equivalent to fertiliser) supplied.
3. Aim for biosolids to supply no more that 50-60% of the total N requirement of the crop, with manufactured fertiliser used to supply the balance. This will minimize the potential impact of (any) variations in biosolids N supply on crop yields and quality.
4. Make sure that application equipment is well maintained and suitable for applying biosolids evenly and at the target rate (please refer to the manufacturer's guidance).
5. Use a nutrient management recommendation system to calculate the amount of crop available N and phosphate/potash etc. supplied per application in each field.
6. Calculate the nutrients supplied by biosolids and deduct this from the requirement of the crop. This will give the balance (if any) that needs to be supplied by manufactured fertiliser.
7. Make use of professionally qualified advice which can be obtained from a Fertiliser Advisers Certification and Training Scheme (FACTS) qualified adviser.

Most farm assurance schemes permit biosolids used in accordance with current legislation and best practice guidance. However, as with the use of all organic materials, farmers and field horticulture producers should check with both their farm assurance scheme(s) and their buyers before using biosolids in their crop production systems.

Table 6. Biosolids (lime stabilised) value to winter wheat

	Nitrogen (N)	Phosphate (P_2O_5)	Potash (K_2O)	Sulphur (SO_3)
Winter wheat requirement (kg/ha)[a]	190	65	85	40
Total nutrients supplied by 20t/ha fresh weight of lime stabilised biosolids (kg/ha)	212	175	20	185
Manufactured fertiliser required (kg/ha)[b]	158	Nil	65	7
Biosolids value in year 1[c]	£25	£49	£9	£5
Biosolids value to following crops[c]	£17	£83	-	-
Total biosolids value	£42	£131	£9	£5
			Total[d]	£211/ha (£86/acre)

a Based on winter wheat grown on medium textured ADAS P Index 2 and K Index 2- soils (SAC moderate)
b Based on biosolids crop available N and SO_3 = 15% of total N (i.e. 32 kg/ha N) and SO_3 applied (i.e. 28 kg/ha SO_3)
c Assuming N = 80p/kg; P2O5 = 75p/kg; K2O = 45p/kg; SO3 = 18p/kg (based on 2018 prices)
d Includes 1.6 t/ha liming value based on lime at £15/tonne (i.e. £24/ha)

Table 7. Biosolids (digested cake) value to oilseed rape

	Nitrogen (N)	Phosphate (P_2O_5)	Potash (K_2O)	Sulphur (SO_3)
Oilseed rape requirement (kg/ha)[a]	160	50	40	75
Total nutrients supplied by 20t/ha fresh weight of digested cake (kg/ha)	220	220	12	164
Manufactured fertiliser required (kg/ha)[b]	127	Nil	28	50
Biosolids value in year 1[c]	£26	£38	£5	£5
Biosolids value to following crops[c]	£18	£128	-	-
Total biosolids value	£44	£165	£5	£5
			Total	£219/ha (£89/acre)

a Based on oilseed rape grown on medium textured ADAS P Index 2 and K Index 2- soils (SAC moderate)
b Crop available N and SO_3 = 15% of total N (i.e. 33 kg/ha N) and SO_3 applied (i.e. 25 kg/ha SO_3)
c Assuming N = 80p/kg; P2O5 = 75p/kg; K2O = 45p/kg; SO3 = 18p/kg (based on 2018 prices)

Table 8. Biosolids (digested cake) value to grassland

	Nitrogen (N)	Phosphate (P_2O_5)	Potash (K_2O)	Sulphur (SO_3)
1st cut grass silage requirement (kg/ha)[a]	100	40	80	40
Total nutrients supplied by 20t/ha fresh weight of digested cake (kg/ha)	220	220	12	164
Manufactured fertiliser required (kg/ha)[b]	67	Nil	68	15
Biosolids value in year 1[c]	£26	£30	£5	£5
Biosolids value to following crops[c]	£18	£135	-	-
Total biosolids value	£44	£165	£5	£5
			Total	£238/ha (£95/acre)

a Based on first cut grass silage grown on ADAS P Index 2 and K Index 2 - soils (SAC moderate)
b Based on biosolids crop available N = 15% of total N applied (i.e. 33kg/ha N); crop available SO_3 = 20% of total SO_3 applied (i.e. 25 kg/ha SO3)
c Assuming N = 80p/kg; P2O5 = 75p/kg; K2O = 45p/kg; SO3 = 18p/kg (based on 2018 prices)

Sources of information

Biosolids Assurance Scheme
https://assuredbiosolids.co.uk

Biosolids Nutrient Management Matrix
http://www.adas.co.uk/Downloads/Biosolids_Nutrient_Management_Matrix.pdf

Code of Practice for Agricultural Use of Sewage Sludge. UK Department of the Environment
http://adlib.everysite.co.uk/resources/000/247/164/sludge-report.pdf

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www.factsinfo.org.uk

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The Safe Sludge Matrix: Guidelines for the Application of Sewage Sludge to Agricultural Land, 3rd Edition
https://assuredbiosolids.co.uk/wp-content/uploads/2017/07/Safe-Sludge-Matrix-2001.pdf

This guide is based on the output from UK Water Industry Research (UKWIR) project 14/SL/11/7.

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