Final Project Bulletin 2016

Using digestate in landscape markets




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OMK004 (please use this reference when citing WRAP's work):
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Front cover photography**:** [top left: Short rotation willow coppice, Chisnall Hall; top right: perennial wild flowers, Cotesbach; bottom left: turf trial applied with digestate; bottom right: fibre digestate at Boston former landfill.

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Introduction

Anaerobic digestion (AD) is undergoing rapid and widespread growth in the UK, with 220 AD plants operational and many more in the planning and commissioning stages. As reported in the first Landscape & Regeneration Bulletin published in 2013, by 2020 the amount of food-based digestate produced annually is predicted to rise to 5 million tonnes (DECC and Defra, 2011) and AD plant capacity would appear to be on track to meet these levels.

In spring 2012 WRAP commissioned a series of demonstration trials designed to evaluate the use of food-based digestate across a diverse range of markets in the landscape and regeneration sectors. This included growing energy crops on brownfield sites and the production and maintenance of sports turf.

The first bulletin explained the AD process and discussed the factors to consider when using digestate, such as how much digestate to use and how and when best to apply it. When compared with PAS 100 green compost, digestate provides higher levels of readily available nutrients, principally nitrogen (N), phosphorus (P) and potassium (K), with useful quantities of sulphur and trace elements. The levels of nutrients provided relate directly to the feedstock from which the digestate is derived. In other words "what goes in comes out", albeit converted into more readily available forms by the AD process.

There are three potential forms of digestate available for use: whole digestate (typically around 4 to 6% dry matter), separated liquor fraction (for use as a liquid fertiliser) and fibre fraction (typically around 23 to 28% dry matter), which supplies both nutrients and organic matter.

This final project bulletin includes a review of the results and conclusions from four projects in the programme, as well as a discussion of practical recommendations from the research teams.

Regeneration Sector

Growing biomass energy crops on brownfield sites

Growing energy crops on restored brownfield sites presents an opportunity for landowners to generate income from harvested biomass, which are typically turned into bricks or pellets for biomass power stations or smaller scale boilers.

This project was undertaken over a two year period at three experimental sites.

The first two sites were on a former landfill site at Boston, Lincolnshire and on a restored colliery at Bilsthorpe, Nottinghamshire. Here the effects of incorporating five different treatments (Table 1) to the existing substrate to establish and grow energy crops were evaluated. The treatments were then subdivided and planted with miscanthus, reed canary grass (RCG) and ryegrass.

Table 1: Field trial treatments at Boston and Bilsthorpe

Treatment	Primary treatment details
Untreated control	No organic material addition
Standard industry practice - Green compost	Incorporated at 400t/ha fresh weight (fw) into the on-site mineral material to a depth of 40 cm at site establishment
Whole digestate	Incorporated at 50 m^3/ha (fw) into the on-site mineral material to a depth of 40 cm at site establishment; plus a further 50 m^3/ha fw application in spring 2013 at the start of active crop growth
Fibre digestate	750 t/ha (fw) incorporated into the on-site mineral material to a depth of 40 cm at site establishment
Standard practice -green compost plus additional whole digestate	400 t/ha (fw) green compost plus 50 m^3/ha of whole digestate incorporated into the mineral material to a depth of 40 cm at site establishment, plus 50 m^3/ha on-site whole digestate in spring 2013 at the start of active crop growth.

The third experimental site was a former landfill site at Burntstump, Nottinghamshire. This project entailed application of whole digestate at different rates (Table 2) as a *biofertiliser* to an established short rotation coppice (SRC) willow using an adapted irrigation system.

Irrigation system at Burnstump trial site

Table 2: Treatments at Burntstump

Treatment No	Treatment details
1	*Untreated control* – no organic material additions. *Note*: this was 'standard practice' at Burntstump.
2	*Food-based digestate applied at c.360 kg/ha/yr total N*, applied in a 50 m^3/ha 'dose' during the growing season using an irrigation system.
3	*Food-based digestate applied at c.720 kg/ha/yr total N*, applied in two 50 m^3/ha 'doses' throughout the growing season, using an irrigation system.
4	*Food-based digestate applied at c.1,080kg/ha/yr total N*, applied in three 50 m^3/ha 'doses' throughout the growing season, using an irrigation system.
5	*Food-based digestate applied at c.360 kg/ha/yr total N*, applied in a 50 m^3/ha 'doses' during the growing season, using an irrigation system, *plus nitrification inhibitor (DCD)*.
6	*Food-based digestate applied at c.360 kg/ha/yr total N*, applied in a 50 m^3/ha 'doses' during the growing season, using an irrigation system, *plus irrigation water*.

Soil physical, chemical and biological characteristics were assessed along with crop performance (yield and herbage nutrient and total heavy metal contents) at all three sites.

Results at Boston and Bilsthorpe

Fibre digestate applied at 750t/ha fresh weight at 28% dry matter was used very effectively to improve soil quality at both sites. At Boston, organic matter in the topsoil almost doubled with the incorporation of fibre digestate, which led to improved physical structure and increased soil biological activity (an indication of a healthy soil). The improved soil quality led to higher yields of both ryegrass (Figure 1) and reed canary grass (Figure 2), which, due to the added benefits of readily available N and P, were higher than *Standard practice* where PAS100 green compost was used alone.

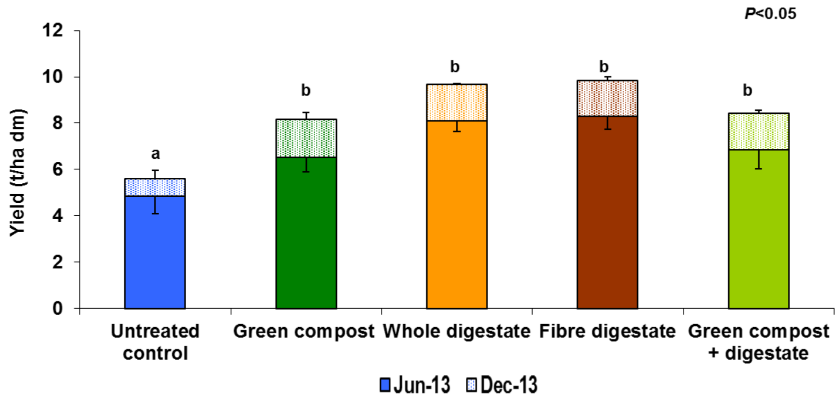

Figure 1 Rye grass yields at Boston 2013

[a,b,] Different letters between bars indicate significant differences between treatments at *P*<0.05; statistical analysis undertaken using ANOVA (data normally distributed).

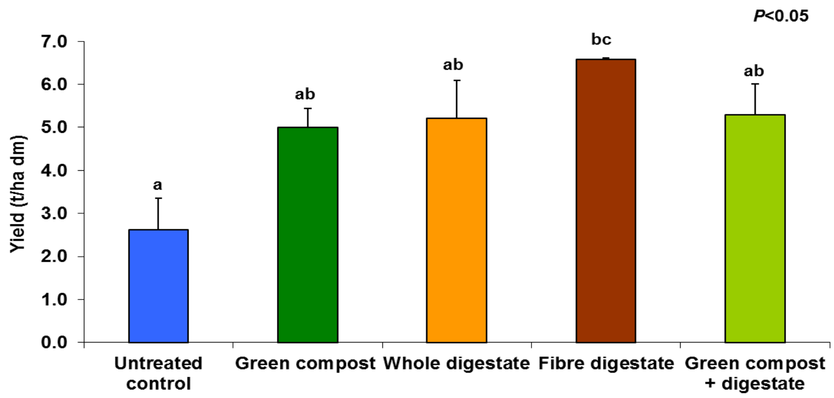

Figure 2. Reed canary grass yields at Boston, December 2013

[a,b,]Different letters between bars indicate significant differences between treatments at *P*<0.05; statistical analysis undertaken using ANOVA (data normally distributed).

Miscanthus yields remained relatively low. However, it is too early to assess its performance at these sites, as the crop does not reach full yield potential for 4-5 years following establishment.

At Bilsthorpe, where the underlying 'mineral material' was virtually pure colliery shale, the energy crops struggled to establish following the whole digestate application, which was probably due to the low amounts of organic matter applied.

Results at Burntstump

The SRC willow did not respond to the digestate applications. Nevertheless the trial did demonstrate the benefits of using organic materials, such as compost and digestate to soil quality. The use of irrigation equipment to apply the digestate initially proved problematic as the solids within the digestate blocked the nozzles. They therefore had to be adapted to cope with the dry matter content of >4%.

Growing perennial flowering plants as an AD feedstock on brownfield sites

Growing perennial herbaceous plants as an AD feedstock offers an alternative to the more traditional energy crops grown on brown field sites. They are relatively cheap to establish, provide an opportunity to enhance soil fertility as many are legumes (able to fix nitrogen from the atmosphere), and have abundant roots to bind and stabilise soils, reducing soil erosion risk. They also provide a diverse habitat for insects and wildlife and can be productive for five years with limited management requirements.

This two year project examined the effects of using separated liquor digestate in combination with PAS100 green compost as a soil improver to grow perennial flowering plants on a capped landfill site at Roxwell, Essex and on a soil bund on a quarry site at Cotesbach, Leicestershire.

At each site, the trial areas were cultivated and then applied with amendments which were then incorporated into the existing soil substrate. All amendments were applied at an equivalent rate of 250 kg/ha of total nitrogen (Table 3).

Table 3: Treatments at Roxwell and Cotesbach

	Treatment	Annual application rate
1	Control	No application
2	Synthetic fertiliser	NPK at standard rates for grass silage, split application: 150kg N/ha in spring, 100kgN/ha in the summer *21:8:11 compound fertiliser Yara Mila New 52*
3	Compost	Single application in spring at 250kg N/ha (57t/ha in 2012, 45t/ha in 2013)
4	Digestate liquor	Single application in spring at 250kg N/ha ($74m^3$/ha in 2012, 64 t/ha in 2013)
5	Digestate liquor	Split application: 150kg N/ha in spring ($45m^3$/ha in 2012, $38m^3$/ha in 2013) 100kgN/ha in summer ($29m^3$/ha in 2012, $26m^3$/ha in 2013)
6	Compost and digestate liquor	Compost at 150kg N/ha in spring (35t/ha in 2012, 27t/ha in 2013) Digestate at 100kgN/ha in summer ($29m^3$/ha in 2012, $26m^3$/ha in 2013)

Each plot was then sown with a 'drought resistant herbal ley' seed mix with the aim of achieving steady growth of biomass throughout the growing season. The crop was assessed monthly at both sites during the growing season and harvested intermittently when it reached a height of 40cm to estimate yield and the crop's biogas potential per hectare.

Soils were sampled and analysed from each site at the beginning of the trial before and immediately after amendments were applied. They were then resampled and analysed at the end of the trial in March 2014.

Results

The exceptionally wet weather conditions encountered in 2012 proved challenging, and the Roxwell trial had to be re-established in spring 2013. Establishment was much better at Cotesbach, although growth was slower to get going on the plots to which compost had been applied.

Both the digestate and the synthetic fertiliser applications increased the levels of soil available nitrogen. At Cotesbach four harvests were taken in 2013 and the plots applied with a split application of digestate had the greatest yield of 15/t/ha fresh weight (fw) compared to 7.1t/ha (fw) on three control plots.

Biogas potential was estimated for both sites using the Baserga equation. Maximum biogas potential resulted from the split digestate treatments on both sites and was calculated at 1614m^3/ha at Cotesbach and 698m^3/ha at Roxwell based on a biogas potential of 473m^3/t (dry matter) of harvested crop

The relatively poor harvest compared to standard energy crops such as maize and rye grass grown on agriculture land with typical yields of 40t/ha (fresh weight) highlights the challenges of growing crops on brownfield land with poor soils. Adequate soil improvements prior to crop establishment is essential to achieve successful plant growth.

Establishing trees and reed canary grass on brownfield land

Historically land restoration projects have failed because insufficient nutrients and organic matter are added to the site to help re-establish plant growth. In the first Landscape & Regeneration Bulletin, we described the impact digestate had during the first growing season at the field trials carried out on the former colliery site at Chisnall Hall, Lancashire. The second year results are discussed here.

In 1976 attempts were made to establish grass and woodland on the acid colliery waste deposited at Chisnall Hall, however large areas of the site remained unproductive. The intention of this trial was to improve the soil's physical and chemical characteristics to establish and grow tree species, namely ash and cherry and energy crops such as willow and reed canary grass (RCG).

The replicated field trial comprised of six treatments: four included digestate either alone or in combination with compost like output (CLO); one included CLO only and another was left untreated as a control (Table 4). All amendments were applied and mixed into the existing substrate to a depth of 1m.

Table 4: Field trial treatments at Chisnall Hall

Treatment	Digestate fibre (t/ha)	Compost Like Output (CLO) (t/ha)
High rate digestate	1875	-
Low rate digestate	937.5	-
High rate digestate + CLO	1875	750
Low rate digestate + CLO	937.5	750
CLO only	-	750
Control	-	-

Tree performance and the growth of the RCG were monitored throughout the 18 month project between May 2012 and August 2013 and in the second growing season both height and oven dry biomass were used as measures of willow and reed canary grass performance. Tree height was used as the performance measure for ash and cherry. Soils were also sampled and analysed on four separate occasions.

Results

The first growing season saw significant mortality of cherry and willow saplings, which was most likely due to the release of ammonia from the high ammonium nitrogen content and high electrical conductivity (EC) of the digestate. By the end of the second growing season (October 2013) however soil analysis confirmed that ammonium nitrogen and EC levels had fallen significantly and were more conducive to plant growth.

The second year analysis of the willow showed that of those trees that had survived from the first year, greatest biomass yields were found on plots applied with low rates of digestate and CLO. The cultivar Terra Nova did particularly well with a maximum mean yield of 19.98 oven dried tonnes (odt)/ha.

RCG was more able to cope with the initial conditions created by the digestate and by the end of the second year; yields had significantly increased particularly on plots where the lower rate of digestate had been applied or where it had been applied with CLO (Figure 4).

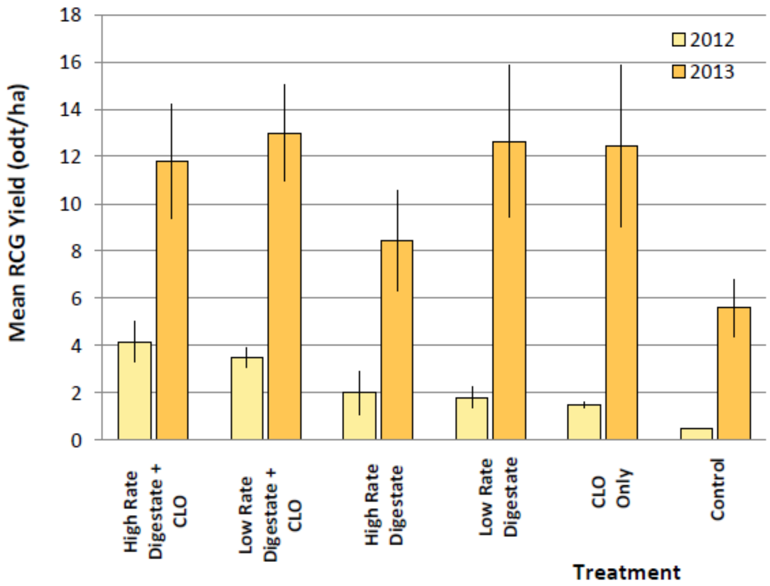

Figure 3: Reed canary grass biomass yields (odt/ha) harvested November 2013

Eighteen months after amendment with digestate and/or CLO there were several beneficial effects on soil chemical and physical properties. There was a moderate increase in percentage soil organic matter content, combined with a reduction in dry soil bulk density (based on disturbed soil). There was also a significant increase in the concentration of the major nutrients for both total N and P and available N and P.

Challenges

The fibre digestate used at Chisnall Hall had a 21.6% dry matter content and proved to be 'sticky' and difficult to handle and incorporate evenly into the soil. Use of digestates with a higher dry matter is recommended and can be achieved with further de-watering in the AD process.

This trial demonstrates that whole digestate with its high nutrient content needs to be applied with caution. In addition the rates of application should be based on existing soil characteristics as well as plant nutrient requirements, balancing organic matter and nutrient requirements. The high tree mortality rates observed in the first year demonstrates the need to analyse the digestate prior to application and ensure that the digestate has been sufficiently stabilised (matured) before applying to land. Significantly lower application rates would have been sufficient for successful plant establishment and growth. The greatest success can be achieved with an integrated approach, using digestate from which nutrients can be easily accessed with other organic materials such as compost that can provide sufficient organic matter.

Materials that are not certified to PAS100 can have significantly higher levels of Potentially Toxic Elements (PTEs) such as lead, copper and chromium. As demonstrated in this trial, these metals increased significantly in plots applied with CLO and can be taken up by the growing plants. It is therefore recommended that amendments are tested for PTEs before they are applied to a site as the increase PTE levels in the plants can prohibit access to the biomass market.

Higher value markets

Amenity and sports turf production

As part of the investigation into high value markets, WRAP investigated the potential of using digestate as a fertiliser in amenity and sports turf production. In order to maintain optimum growth, sports turf demands high inputs of nutrients, usually provided by inorganic fertilisers. This project set out to determine if liquid fraction digestate could potentially replace proprietary fertiliser and to assess the potential risks associated with using digestate in this market.

The project consisted of two identical ryegrass field trials, one of which was located on heavy soils at Myerscough College, Lancashire and the other located on the lighter soils at Silsoe, Cranfield University, Bedfordshire. Both examined the surface application of liquid fraction food-based digestate against a proprietary fertiliser commonly used in turf maintenance with 12%N, 4%P and 6%K content. Digestate was applied at two rates - 100kg and 200kg total N/ha over five applications per year for two years. This equated to single application rates of 20kg and 40kg total N/ha respectively, and was compared to mineral fertiliser that was applied at an equivalent of 100 kg N/ha (i.e. 20kg total N/ha per application).

Following the application of the digestate sward quality (greenness index, chlorophyll and nutrient content, sward composition and root growth) and soil chemical, physical and biological characteristics were analysed.

Results

The results showed that when digestate was applied at a rate sufficient to provide 100kg total N/ha per year turf grass quality was equal to plots that were applied with proprietary fertiliser. Nevertheless the digestate supplied only half the amount of phosphorus required, highlighting the need for an integrated approach to nutrient supply. Digestate analyses also showed that the balance of nutrients varied between AD plants and therefore matching turf requirements will be challenging unless further processing is carried out.

There was little impact on the soil's physical, biological and chemical characteristics however there was a noticeable immediate increase in sodium content and a reduction of mycorrhizal colonisation (an indication of soil health) with high rates of digestate application. The mycorrhiza are important for pathogen protection, water supply and nutrient uptake, however long term affects were not assessed and therefore further study would be required before any conclusions can be made from these observations.

Challenges

The risk assessment carried out on this project showed that digestate is safe to use for turf production, however other challenges were identified such as odour, gaseous build up in storage containers and the potential for staining of clothes during application. All these would need to be overcome before using digestate for this purpose.

Surface application of fertilisers is commonly used in sports turf production however applying digestate in this way was found to be impractical as the organic matter in the digestate caused the application nozzles to block. Further processing of the digestate is required to provide a consistent, fit for purpose fertiliser for high value markets. The project demonstrated that there is potential to use digestate as a turf fertiliser however the barriers highlighted above will need to be addressed before it can be used in this market.

In summary

It has been demonstrated from this programme that digestate could be utilised for biomass production on brownfield land as it provides a good source of nutrients, particularly available N and, in the case of fibre digestate, organic matter too. Nevertheless the practicalities of using digestate depend on the existing soil characteristics of the site and requirements for nutrients and organic matter, the ease of application and the logistics and economics of supply. Specifying compost and digestate produced to PAS100 and PAS110 as opposed to non-compliant organic materials such as CLO provides confidence in the materials, and needs to be weighed up against economic viability.

Likewise there is potential to use digestate as a fertiliser in higher value markets. However further processing is needed to improve the quality and consistency of the material. In addition, further research and development is required to develop suitable products that could be used in this market and to some extent this has been investigated through WRAP's ***Optimising digestate value and digestion systems programme***.

Conclusions

Using PAS100 or PAS110 accredited compost and digestates provides confidence to the land owner that the material is safe to use and does not cause significant increases in potentially toxic elements (PTE) levels in the growing biomass. Nevertheless organic materials can be expensive to transport and therefore the cost may be prohibitive so this would need to be assessed on a site by site basis.

Fibre digestate supplies good amounts of organic matter and higher amounts of valuable nutrients than composts. To harness the nitrogen from digestate effectively and reduce potential losses to the wider environment, the material needs to be properly matured and incorporated into the soil, before plants are established in time for when their nitrogen requirements are greatest. Where brownfield land soils are in poor condition, plant growth may be limited and therefore nutrient uptake ineffective, resulting in the risk of greater losses to the environment. It is therefore recommended that a site specific risk assessment is carried out before organic materials are used (a requirement of Environmental Permitting Regulations (SI, 2010)) even if they have product status.

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