PAS 110: Public Consultation Supporting information

The following information provides a rationale for the amended limits shown within the redrafted specification. They cover four areas:
1. Pasteurisation
2. PTEs
3. Physical contaminants
4. Stability

Please note that supporting data is available on request from david.tozer@wrap.org.uk for the four areas noted.

1. Options for improving the flexibility of the PAS110 pasteurisation approaches

Overview

Clause 7.2.1 has been amended, to address feedback from operators accepting only non-ABP, in recognition of the fact that some of those feedstocks will derive from processes including adequate thermal processing to manage phytohygiene hazards, and that other operators may wish to implement non-standard sanitisation approaches to deliver appropriate phytohygiene hazard control.

Clauses 7.2.2 and 7.2.3 have been amended to allow AD operators processing a limited number of non-ABP feedstocks (manure, unprocessed crops, processed crops, crop residues and glycerol) to omit these feedstocks from the pasteurisation requirement, where they arise from and are returned to (in the form of digestate) a co-operative. This is a slight extension to the existing approach, which required that these materials arise from, be processed on and returned to the same holding. Extending the approach to a co-operative model should allow more flexibility, but the omission of a specific phytohygiene management step (other than anaerobic digestion itself) for these materials means that those receiving the digestates must be alerted to this and decide for themselves whether the digestate is of sufficient quality for their purposes.

Background

Please note that this section has been copied-across from the document *Options for updating PAS110* that was widely circulated during the PAS review process. Copies of the full document are available on request from WRAP[1].

At present any AD process accepting feedstocks that include animal by-products (ABP) must include a pasteurisation step. This is a statutory requirement, and PAS110 provides no opt-out to this requirement. There is no suggestion that PAS110 could provide an opt-out to the statutory ABP pasteurisation requirement. However, there is no such regulatory requirement covering AD processes accepting only crops grown for AD, or other non-ABP such as vegetable processing residues.

Due to uncertainties around the plant health risks associated with digestates derived from non-pasteurised plant residues, PAS110:2010 processes must include a pasteurisation step for these non-ABP inputs in most circumstances. Exceptions are listed in PAS110:2010 Clauses 7.2.2 and 7.2.4:

7.2.2 Digested materials made only from manure, unprocessed crops, processed crops, crop residues, glycerol, and/or used animal bedding that arise within the producer's premises or holding and that are used entirely within the same premises or holding are exempt from the pasteurization step (7.2.1)… This clause does not apply to a farming / horticultural / forestry co-operative (see 3.28).

[1] Please email David.Tozer@wrap.org.uk

7.2.4 Exemption from the pasteurization step (7.2.1) is also allowed for manure, unprocessed crops, processed crops, crop residues, glycerol, and/or used animal bedding (see 7.2.3 for allowed source before use) that arises within the producer's premises or holding, if such input materials are co-digested with pasteurized biodegradable materials / wastes from any source(s) outside the producer's premises or holding. This material source-specific exemption from pasteurization is conditional upon all the digested material being used within the producer's premises or holding, irrespective of whether it is part of a farming / horticultural / forestry co-operative (see 3.28).

In brief, this means that pasteurisation of manure, unprocessed crops, processed crops, crop residues, glycerol and/or used animal bedding is not required – if the resulting digestate is applied on the same premises or holding from which those materials arose. The same exemption applies when these materials are mixed with other feedstocks – so long as those other feedstocks have been pasteurised.

Such a system could be represented like this:

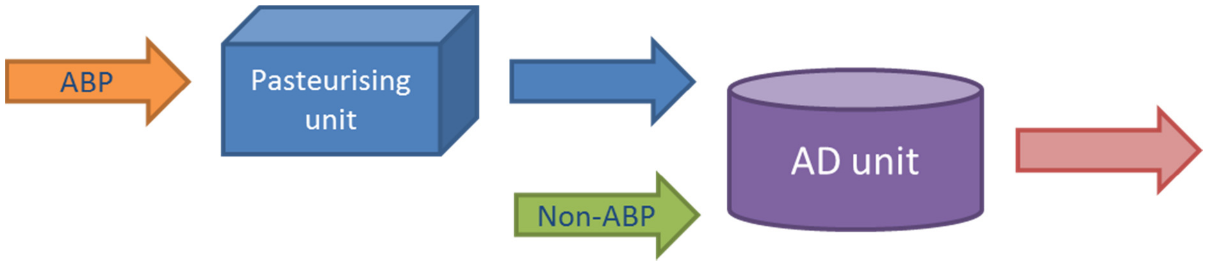

Figure 1

At the moment the use of the digestates from these systems are restricted to the 'premises or holding' from which the eligible non-pasteurised non-ABP inputs arose.

It has been suggested that – now that more information is available on plant health risks – the current PAS110 pasteurisation approach to non-ABP feedstocks could be re-considered.
As part of the pre-consultation leading up to the PAS110 review, WRAP circulated a report from Fera (Food & Environment Research Agency) that examined the impacts of AD with and without pasteurisation on a range of plant diseases of interest. This showed that all of the organisms under investigation would be eliminated if subjected to 24 hours under mesophilic anaerobic digestion conditions (without pasteurisation) or within one hour at 70°C (pasteurisation).

Pasteurisation processes are designed not to be by-passed, so that all input material can be guaranteed to have been subjected to the required time at the required temperature.

In continuous or semi-continuous fill-and-draw AD systems, there is a possibility that some of the input material will not be subjected to 24 hours of anaerobic digestion. This means that there is a small (although un-quantified) risk that untreated plant material could be present in the digestate, when produced from systems that do not include a pasteurisation step.

Set against this, it should also be considered that, when the only inputs to an anaerobic digestion process are crops grown specifically for AD (such as maize), the resulting digestate is not considered a waste, and could be used freely on any agricultural land / crop within the boundaries of Codes of Good Agricultural Practice (and other umbrella restrictions, such as those imposed in Nitrate Vulnerable Zones). If manures are added as another feedstock in these systems, then the environmental regulators are also content not to regulate the resulting digestates as wastes[2], which can then be transported and used freely. Pasteurisation is not required for either of these systems.

The discussion in the Steering Group (and subsequently, with farm assurance groups) has focussed on the possible survival of the spores of *Fusarium* fungi during AD, when the system does not include a pasteurisation phase. When certain *Fusarium* species infect wheat crops, mycotoxins can be produced that

[2] http://www.environment-agency.gov.uk/static/documents/Research/PS_029_AD_of_agricultural_manures_and_slurry_final.pdf

impact on the quality and usability of the wheat grain. Maize is known to be a host for mycotoxin-forming *Fusarium* species, and the risks from maize crop residues to following wheat crops are factored into the HGCA mycotoxin risk assessment[3]. This risk assessment contains no explicit reference to maize-based digestates.

Evidence suggests that *Fusarium* spores are killed during pasteurisation at 70°C for one hour, or exposure to mesophilic anaerobic digestion conditions for twelve hours. For example, Figure 2 presents data showing complete inactivation of *Fusarium* spores in infected grain within twelve hours under both mesophilic and thermophilic conditions.

Figure 2 also illustrates the impact of different fermentation / digestion treatments on the survival of *Fusarium* spores in infected grain (from Frauz B, Weinmann U, Oechsner H & Jungbluth T (2007) *Disposing of Contaminated Grain Batches* Landtechnik 5: 334 – 335)

Operation	Operation temperature	Substrate	Arrangement of inoculation	Duration of fermentation	Evidence of complete inactivation
Batch, Liquid-fermentation	mesophil (37°C)	mould-free material	isolated spores	0 - 96 hours	3,5 hours
Batch, Liquid-fermentation	mesophil (37°C)	moulded material	naturally in-fected cereals	12 hours - 35 days	12 hours
Batch, Liquid-fermentation	thermophil (53°C)	moulded material	naturally in-fected cereals	12 hours - 35 days	12 hours
Batch, solidphase digestion	mesophil (37°C)	moulded material	naturally in-fected cereals	12 hours - 35 days	12 hours

Figure 2

There is also some evidence to suggest that the act of ensiling maize (prior to anaerobic digestion) also kills *Fusarium* spores. Figure shows the recovery of a range of fungi from maize at harvest and then after ensilement. The *Penicillium* species were recovered from the ensiled maize, whilst the *Fusarium* species were not.

The findings of other authors are more equivocal. For example González Pereyra *et al* (2008)[4] isolated viable spores of various *Fusarium* species from maize silage in Argentina.

Figure 3 Mycotoxigenic *Penicillium* and *Fusarium* species isolated from maize at harvest and after ensiling (from Mansfield MA & Kuldau GA (2007) *Microbiological and molecular determination of mycobiota in fresh and ensiled maize silage* Mycologia 99(2): 269 – 278)

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[3] http://www.hgca.com/document.aspx?fn=load&media_id=8828&publicationId=9293

[4] Pereyra ML González, Alonso VA, Sager R, Morlaco MB, Magnoli CE, Astoreca AL, Rosa CAR, Chiacchiera SM, Dalcero AM, Cavaglieri LR (2008) Fungi and selected mycotoxins from pre- and postfermented corn silage Journal of Applied Microbiology 104(4): 1034 - 1041

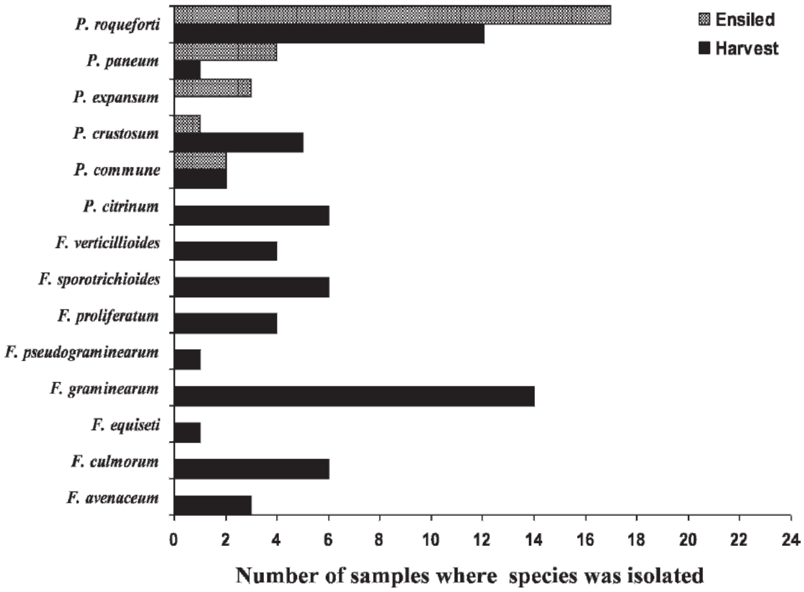

Figure 3

It has been suggested that this information should permit the use of digestates derived from maize feedstock on a wider range of premises than is permitted by PAS110:2010. This could mean use of such digestates within co-operatives or other entities that provided the maize feedstock – since this allows those entities to maintain 'line of sight' of the digestate, understanding and managing any residual *Fusarium* risks. It could also mean allowing the use of such digestates on the open market, although the discussions to date have indicated that further evidence would be desirable before this step could be taken.

Since the discussion has focussed on the potential fate of *Fusarium* species associated with maize feedstocks, it is not possible to generalise about the potential fate of other plant pathogens that might be associated with other feedstocks currently exempt from pasteurisation as described in Clauses 7.2.2 and 7.2.4 of PAS110:2010. However, the general principle of maintaining 'line of sight' for such digestates could also be applied to these materials.

An additional facet is encountered at AD facilities that accept non-ABP 'waste' materials, such as vegetable off-cuts from produce grown overseas and processed in the UK. At present, such operators have three time/temperature/particle size options for pasteurisation (PAS110:2010, Annex A), including 70°C for one hour at 12mm. If they want to use a different option, then this currently has to be validated by Animal Health (AHVLA) – even though the process is not accepting (and not intending to accept) Animal By-Products.

Could such facilities adopt a specific plant health validation step, which demonstrates the effectiveness of their time/temperature regime by elimination of a pre-determined indicator organism (such as club root of brassicas)? Such an approach is already in place in Germany, which comprises a phytohygiene validation regime based on survival of tobacco mosaic virus, club root of brassicas and tomato seeds[5].

Furthermore, there are situations where the entire AD feedstock will already have undergone a prior thermal treatment process. Is it reasonable that PAS110 require that these be subjected to a further pasteurisation step, even if they originate from processes that exceed the standard pasteurisation options recommended in PAS110:2010 (Annex A)? Distillery residues would be one example. How would one judge whether or not these materials had undergone treatment that had met or exceeded the standard pasteurisation options recommended in PAS110:2010 (Annex A)? Pasteurisation units (PU) are used in other food processing sectors to determine equivalence between different time/temperature regimes[6]. Could the principle be adopted into PAS110?

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[5] http://www.ramiran.net/doc98/FIN-POST/BOHM.pdf
[6] http://sizes.com/units/pasteurization_unit.htm

2. WRAP proposal to the PAS110 steering group and environmental regulators, for digestate PTE limits set on a fresh matter basis

Overview

Following a request from industry representatives on the PAS110 steering group during a meeting held on 24th October 2013, WRAP have taken the NRM laboratories' PTE data compiled by REA and ADBA, and used the ADAS methodology[7] to propose fresh matter PTE limits for digestates. It was suggested that WRAP ask ADAS to undertake this modelling, but to save time (and cost) it has been undertaken in-house by WRAP.

In line with the proposed timetable laid out in Bhavisha Patels's email of the 6th November, the three tables presented below will be included in the draft PAS110 that steering group members will have an opportunity to comment on before it is subjected to public consultation. This paper summarises the approach to derivation of the proposed limits, with the actual data presented in the accompanying spreadsheet 'PTE proposal'.

Please note that none of these Options is expected to increase the cost of digestate testing in PAS110.

Option 1

N-tot concentration (kg/t) fw	≤3	>3 to 5	>5 to 7	>7 to 9	>9
PTE limits*					
Cd	0.12	0.36	0.6	0.84	1.08
Cr	8	24	40	56	72
Cu	16	48	80	112	144
Hg	0.08	0.24	0.4	0.56	0.72
Ni	4	12	20	28	36
Pb	16	48	80	112	144
Zn	32	96	160	224	288

Option 2

PTE limits*	Liquid digestates	Fibre digestates
Dry matter (% m/m)	<15%	≥15%
Cd	0.2	0.2
Cr	5	20
Cu	15	40
Hg	0.1	0.1
Ni	3	10
Pb	5	30
Zn	30	150
*mg/l for liquid digestates mg/kg for fibre digestates		

Option 3

PTE limits*	Limit for liquid digestates		Limit for fibre digestates	
Dry matter (% m/m)	<15%		≥15%	
N-tot concentration (kg/t) fw	≤3	>3	≤3	>3
Cd	0.1	0.2	0.1	0.2
Cr	5	5	5	20
Cu	15	15	15	40
Hg	0.1	0.1	0.1	0.1
Ni	3	3	3	10
Pb	5	5	5	30
Zn	30	30	30	100

[7] Developed by ADAS in their report for WRAP (*An examination of limits for potentially toxic elements (PTEs) in anaerobic digestates*)

*mg/l for liquid digestates mg/kg for fibre digestates

Approach

Theoretical annual PTE loading rates are calculated for PAS100 composts, since these are considered acceptable maxima. These loading rates are calculated using the total nitrogen (N-tot) concentration in compost as a limiting factor. Compost is applied at a rate sufficient to provide 250kg/ha of N-tot. This nitrogen loading is the maximum permitted in Nitrate Vulnerable Zones, and also the maximum annual rate under the Code of Good Agricultural Practice.

Using RB209 data for green composts (since these contain less N-tot than green/food composts, and could be applied at a higher rate, representing a realistic worst-case scenario), a theoretical application rate of 250/7.5 = 33.33333t/ha of compost is calculated (Table 1).

Table 1. RB209[8] data for green composts

Dry matter	60	%	
N-tot	7.5	kg/t	fresh
Application rate	33.33333	t/ha	fresh

Using the dry matter figure listed in Table 1, it is possible to calculate the fresh matter concentration for PAS100 composts (Table 2).

Table 2. PAS100 PTE limits expressed on dry and fresh matter bases

	DRY			FRESH	
Cd	1.5	mg/kg		0.9	mg/kg
Cr	100	mg/kg		60	mg/kg
Cu	200	mg/kg		120	mg/kg
Hg	1	mg/kg		0.6	mg/kg
Ni	50	mg/kg		30	mg/kg
Pb	200	mg/kg		120	mg/kg
Zn	400	mg/kg		240	mg/kg

Using the application rate listed in Table 1, and the fresh weight PTE concentrations listed in Table2, it is possible to calculate fresh weight PTE loadings for PAS100 compost (Table 3).

[8] Defra's Fertiliser Manual

Table 3. Theoretical PTE loading rates for PAS100 compost, expressed on a fresh weight basis

Cd	30	g/ha		0.03	kg/ha
Cr	2000	g/ha		2	kg/ha
Cu	4000	g/ha		4	kg/ha
Hg	20	g/ha		0.02	kg/ha
Ni	1000	g/ha		1	kg/ha
Pb	4000	g/ha		4	kg/ha
Zn	8000	g/ha		8	kg/ha

Using this same approach, it is possible to calculate the application rates for digestates at different N-tot concentrations (Table 4), and using a simple back-calculation, to determine the theoretical fresh weight concentrations of PTEs in digestates that would give the same PTE loading rate as PAS100 composts at these different application rates (Table 5).

Table 4. Calculated rates for digestates with various N-tot concentrations applied to provide 250kg N-tot per hectare

N-tot concentration (kg/t)	<1 to 3	>3 to 5	>5 to 7	>7 to 9	>9
Application rate (t/ha)	250	83	50	36	28

Table 5. Theoretical fresh weight PTE concentrations in digestates (mg/kg) that would give the same PTE loading rate as PAS100 composts at different digestate N-tot concentrations

N-tot concentration (kg/t) fw	≤3	>3 to 5	>5 to 7	>7 to 9	>9
PTE limits*					
Cd	0.12	0.36	0.6	0.84	1.08
Cr	8	24	40	56	72
Cu	16	48	80	112	144
Hg	0.08	0.24	0.4	0.56	0.72
Ni	4	12	20	28	36
Pb	16	48	80	112	144
Zn	32	96	160	224	288

Option 1

Adopt Table 6, which pegs digestate PTE concentrations to digestate N-tot concentrations, ensuring that digestates cannot be applied at rates that would allow PTEs to exceed those permitted for PAS100 composts. This approach is different from that originally proposed by ADAS, but provides digestate users with absolute confidence that PTEs in digestate cannot be applied at rates that would exceed those considered acceptable in PAS100 composts.

These limits would apply equally to whole digestates and any separated fractions. Using this approach, one digestate sample in the NRM dataset would fail for copper (Cu), and two would fail for nickel (Ni). These failures are highlighted in the accompanying Excel spreadsheet.

Table 6. Fresh weight PTE concentrations in digestates, varied according to digestate N-tot concentrations

PTE limits*					
N-tot concentration (kg/t) fw	≤3	>3 to 5	>5 to 7	>7 to 9	>9
Cd	0.12	0.36	0.6	0.84	1.08
Cr	8	24	40	56	72
Cu	16	48	80	112	144
Hg	0.08	0.24	0.4	0.56	0.72
Ni	4	12	20	28	36
Pb	16	48	80	112	144
Zn	32	96	160	224	288
*mg/l for liquid digestates mg/kg for fibre digestates					

Option 2

When the limits listed in Table 6 are compared with the dataset in the accompanying Excel spreadsheet, it is clear that digestate PTE concentrations are (with very few exceptions) much lower than those that would be considered acceptable using the approach presented in Table 6. Table 7 therefore suggests absolute limits for liquid and fibre digestates that would be achieved by the vast majority of digestates in the NRM database. This approach is very similar to that proposed by ADAS, and the limits in Table 7 are by and large the same as those proposed by ADAS, with exceptions made to reflect the new dataset. These suggestions are not based on a statistical approach, but a simple visual examination of the data.

One potential advantage of this approach is that it demonstrates a willingness on the part of the AD industry to exceed the standards considered acceptable for PAS100 composts. On the other hand, it has the potential dis-advantage (compared with Option 1) of having no in-built PTE application rate limiter, which could give rise to excessive PTE applications where digestates are applied at extremely high rates.

Using this approach, two extra samples would fail on one or more PTEs, when compared with Option 1. These failures are highlighted in the accompanying Excel spreadsheet.

Table 7. Proposed fresh weight PTE limits in digestates, categorised as liquid or fibre

PTE limits*	Liquid digestates	Fibre digestates
Dry matter (% m/m)	<15%	≥15%
Cd	0.2	0.2
Cr	5	20
Cu	15	40
Hg	0.1	0.1
Ni	3	10
Pb	5	30
Zn	30	150
*mg/l for liquid digestates mg/kg for fibre digestates		

Option 3

This is a hybrid between Option 1 and Option 2, providing a 'safety net' to ensure that low-N / high PTE digestates (whether liquid or fibre) do not exceed PAS100 PTE loading rates (Table 8).

Using this approach, one extra sample would fail on one or more PTEs, when compared with Option 2. These failures are highlighted in the accompanying Excel spreadsheet.

Table 8. Proposed fresh weight PTE limits in digestates, categorised as liquid or fibre

PTE limits*	Limit for liquid digestates		Limit for fibre digestates	
Dry matter (% m/m)	<15%		≥15%	
N-tot concentration (kg/t) fw	≤3	>3	≤3	>3
Cd	0.1	0.2	0.1	0.2
Cr	5	5	5	20
Cu	15	15	15	40
Hg	0.1	0.1	0.1	0.1
Ni	3	3	3	10
Pb	5	5	5	30
Zn	30	30	30	100
*mg/l for liquid digestates mg/kg for fibre digestates				

Test methods

During the meeting held on 24th October 2013, the REA representative offered to discuss PTE test methodologies with NRM. This discussion has taken place, and the REA representative has consulted with over 30 AD operators. The result is as follows:

Liquid (<15%) digestates should be tested for PTEs according to method BS 15587-1:2002
Fibre (≥15%) digestates should be tested for PTEs according to method BS EN 13650:2001

The results from either test would be declared on a FW basis to allow comparison against the limit tables.

Note on costs

Changing from BS EN 13650:2001 to BS 15587-1:2002 for liquid digestates is expected to reduce analytical costs, since the latter method does not require large samples of liquid material to be dried down prior to analysis.

Otherwise none of the Options listed in this paper is expected to add to the cost of PAS110 testing, since PTE and N-tot determinations are already required.

3. Options for setting digestate physical contaminant limits set on a fresh matter basis

Overview

Following a request from industry representatives on the PAS110 steering group during a meeting held on 24th October 2013, WRAP have taken the NRM laboratories' physical contaminant data compiled by REA and ADBA, and (following feedback from REA and Biogen) used the methodology developed elsewhere[9] to propose fresh matter physical limits for digestates.

This paper summarises the approach to derivation of the proposed limits, with the actual data presented in the accompanying spreadsheet 'Phys Contam calcs'.

Please note that none of these Options is expected to increase the cost of digestate testing in PAS110.

Option 1	Liquid digestates (< 15%)	Solid digestates (≥15%)
Total PC limit (kg/t) fresh weight	0.2	0.6
Stones >5mm (kg/t) fresh weight	6.4	19.2

Option 2	Applies equally to all digestates and digestate fractions				
N-tot content (kg/t) fresh weight	≤3	>3 to 5	>5 to 7	>7 to 9	>9
Total PC limit (kg/t) fresh weight	0.2	0.6	1	1.4	1.8
Stones >5mm (kg/t) fresh weight	6.4	19.2	32	44.8	57.6

Option 3	Liquid digestates		Solid digestates	
	<15%		≥15%	
N-tot (kg/t) fresh weight	≤3	>3	≤3	>3
Total PC limit (kg/t) fresh weight	0.1	0.3	0.2	0.4
Stones >5mm (kg/t) fresh weight	0.1	0.1	6.4	19.2

Option 4	No change

[9] Developed by ADAS in their report for WRAP on PTE limits in digestates (*An examination of limits for potentially toxic elements (PTEs) in anaerobic digestates*)

Approach

Theoretical annual physical contaminant loading rates are calculated for PAS100 composts, since these are considered acceptable maxima. These loading rates are calculated using the total nitrogen (N-tot) concentration in compost as a limiting factor. Compost is applied at a rate sufficient to provide 250kg/ha of N-tot. This nitrogen loading is the maximum permitted in Nitrate Vulnerable Zones, and also the maximum annual rate under the Code of Good Agricultural Practice.

Using RB209 data for green composts (since these contain less N-tot than green/food composts, and could be applied at a higher rate, representing a realistic worst-case scenario), a theoretical application rate of 250/7.5 = 33.33333t/ha of compost is calculated (Table 1).

Table 1. RB209[10] data for green composts

Dry matter	60	%	
N-tot	7.5	kg/t	fresh
Application rate	33.33333	t/ha	fresh

Using the dry matter figure listed in Table 1, it is possible to calculate the fresh matter concentration for PAS100 composts (Table 2).

Table 2. PAS100 physical contaminant limits expressed on dry and fresh matter bases

	DRY		FRESH	
Total physical contaminants	2.5	kg/t	1.5	kg/t
Stones	80	kg/t	48	kg/t

Using the application rate listed in Table 1, and the fresh weight physical contaminant (PC) levels listed in Table2, it is possible to calculate fresh weight PC loadings for PAS100 compost (Table 3).

Table 3. Theoretical PC loading rates for PAS100 compost, expressed on a fresh weight basis

Total physical contaminants	50	kg/ha
Stones	1600	kg/ha

Using this same approach, it is possible to calculate the application rates for digestates at different N-tot concentrations (Table 4), and using a simple back-calculation, to determine the theoretical fresh weight levels of PCs in digestates that would give the same PC loading rate as PAS100 composts at these different application rates (Table 5).

Table 4. Calculated rates for digestates with various N-tot concentrations applied to provide 250kg N-tot per hectare

N-tot concentration (kg/t) fw	<1 to 3	>3 to 5	>5 to 7	>7 to 9	>9
Application rate (t/ha)	250	83	50	36	28

Table 5. Theoretical fresh weight PC levels in digestates (kg/t) that would give the same PC loading rate as PAS100 composts at different digestate N-tot concentrations

N-tot concentration (kg/t) fw	≤3	>3 to 5	>5 to 7	>7 to 9	>9
Total physical contaminants	0.2	0.6	1	1.4	1.8
Stones	6.4	19.2	32	44.8	57.6

[10] Defra's Fertiliser Manual

Options 1 and 2
Adopt Table 6, which pegs digestate PC levels to digestate N-tot concentrations, ensuring that digestates cannot be applied at rates that would allow PCs to exceed those permitted for PAS100 composts. This approach provides digestate users with absolute confidence that PCs in digestate cannot be applied at rates that would exceed those considered acceptable in PAS100 composts.

These limits would apply equally to whole digestates and any separated fractions. Using this approach, seven digestate samples in the NRM dataset would fail. This compares with fourteen failures under the current approach.

Table 6. Option 2: Proposed fresh weight PC levels in digestates (kg/t), varied according to digestate N-tot concentrations

N-tot concentration (kg/t) fw	≤3	>3 to 5	>5 to 7	>7 to 9	>9
Total physical contaminants	0.2	0.6	1	1.4	1.8
Stones	6.4	19.2	32	44.8	57.6

The approach listed in Table 6 might appear overly-complex to some, for whom single limits for fibre and liquid digestates might be preferable. Various approaches could be taken to derive limit levels under this scenario, but Table 7 simply takes the loading rates from Table 6 and cross-references these with the lowest recorded N-tot concentrations for either liquid or fibre digestates.

Using this approach, twelve digestate samples in the NRM dataset would fail. This compares with fourteen failures under the current approach.

Table 7. Option 1: Proposed fresh weight PC limits in digestates (kg/t), categorised as liquid or fibre

	Liquid digestates	Fibre digestates
Dry matter (% m/m)	<15%	≥15%
Total physical contaminants	0.2	0.6
Stones	6.4	19.2

Option 3
This is a hybrid between Option 1 and Option 2, providing a 'safety net' to ensure that low-N / high PC digestates (whether liquid or fibre) do not exceed PAS100 PC loading rates (Table 8).

When the limits listed in Table 6 are compared with the dataset in the accompanying Excel spreadsheet, it is clear that digestate PC levels are (with very few exceptions) much lower than those that would be considered acceptable using the approach presented in Table 6. Table 8 therefore suggests absolute limits for liquid and fibre digestates that would be achieved by the vast majority of digestates in the NRM database. These suggestions are not based on a statistical approach, but a simple visual examination of the data.

One potential advantage of this approach is that it demonstrates a willingness on the part of the AD industry to exceed the standards considered acceptable for PAS100 composts. Using this approach, eleven digestate samples in the NRM dataset would fail. This compares with fourteen failures under the current approach.

Table 8. Option 3: Proposed fresh weight PC limits in digestates (kg/t), categorised as liquid or fibre

	Limit for liquid digestates		Limit for fibre digestates	
Dry matter (% m/m)	<15%		≥15%	
N-tot concentration (kg/t) fw	≤3	>3	≤3	>3
Total physical contaminants	0.1	0.3	0.2	0.4
Stones	0.1	0.1	6.4	19.2

4. A proposal from AD industry representatives to the PAS 110 Review Steering Group and environmental regulators to refine the existing limit level for the Residual Biogas Potential (RBP) test

Note: The proposed changes to stability level are currently under consideration by the Environmental Regulators and as such are yet to be formally accepted.

1. Premise

Some AD operators including those who have come together to form the AD Operators Working Group[11] consider that the RBP test is not relevant to proving the quality and fitness for purpose of quality digestate, and therefore that it is not relevant within the context of PAS 110 specification. In addition they consider it to be a very costly and time consuming test to carry out.

Ideally, if the PAS 110 review had not already been considerably delayed (see section 2 below), the AD industry representatives recognise that it would have been possible for consideration to have been given to whether the RBP could be replaced by a simpler, cheaper and shorter alternative test method (or appropriate calculation). However, since the current PAS 110 review has already been considerably delayed, these AD operators fear that proposing an alternative method at this point would require further R&D and thus cause significant further delays to the review.

In view of this the AD industry representatives are now proposing to support the retention of the RBP test method in its current form but to change its limit level to a higher value based on sound, available evidence.

The members of the PAS 110 Review Steering Group requested on 24th October that a paper be drafted setting out the position of AD industry representatives and forwarded to them and the Environment Agency. This paper draws on available research including the data made available to the PAS 110 Review Meeting by Renewable Energy Association courtesy of the Biofertiliser Certification Scheme.

The paper does not consider the purpose of the Residual Biogas Potential Test (RBP) itself. However the AD industry representatives consider that clarity has not yet been fully obtained from the environmental regulator on the purpose of the RBP or an alternative test. For this reason we urge the regulator to clarify the purpose of the RBP or an alternative method in the context of compliance with End of Waste criteria, to assist the industry in developing alternatives in the future.

2. Basis for the current RBP test, its limit level and the selection of the current virgin comparator

At the PAS 110 Steering Group meeting held on 13th May 2013 the environmental regulator agreed to provide a summary explaining the basis from European End of Waste criteria and relevant case law for requiring the Residual Biogas Potential or an equivalent test and for selecting an appropriate

[11] TEG Environmental, Biogen, Andigestion, PDM, Agrivert, GWE, Lower Reule, Cannington, Gask Farm, Local generation, Tamar Energy, Swancote Energy , Eco Sustainable Solutions , Biffa , Future Biogas

virgin comparator. This would guide suggestions for alternative comparative materials and limit levels.

On 4th July 2013, one and a half months later, the regulator provided a document entitled *Note on RBP Test and Alternatives*, which explains the basis for requiring the RBP or an equivalent alternative test.

Following repeated requests to the regulator from WRAP and the trade bodies (REA, ADBA and ADOWG) for further clarity, in particular on how virgin comparators could be selected, and how equivalence with virgin comparators could be demonstrated, the Environment Agency supplied further feedback to WRAP on 12th September. Prior to that date, WRAP and the sector trade bodies were unable to secure a meeting with the regulators to obtain clarity on these aspects. This meant that the originally anticipated timescale for the review of PAS110 was subjected to a delay of at least 4 months. As a result, the industry was not sufficiently clear in advance as to whether further R&D work would be required to support the selection of a different virgin comparator, or what the criteria would be for the choice of an alternative test method and/or the setting of a new limit level for the current method.

As explained in the Environment Agency *Note on RBP Test and Alternatives* released last July, the residual biogas potential test (RBP) is required by the regulator to demonstrate equivalence of waste-derived digestates with a virgin comparator (raw material).

The RBP test method was developed by a consortium made up of the University of Southampton (SU), the Open University (OU) and consultancy WRc Plc[12]. As clarified by the consortium in the associated report, at the time the test was developed there was 'a lack of evidence on which to base an RBP value that represents digestate stability and process efficiency'. Consequently it was decided to run parallel tests on a very limited number of other materials commonly applied to land, which included two cattle slurries, two pig slurries and five sewage sludges. It is unclear from the report which types or fractions of cow and pig slurries were analysed. As the budget available for this project was limited, the consortium was not able to analyse a sufficient number of samples to allow the limit level for the RBP to be set on a robust statistical basis.

The virgin comparator currently selected by the regulator is cattle slurry. Based on the RBP values reported by the consortium for the two samples of cattle slurries, a limit of 0.20 l/gVS was considered for PAS110 digestates. However, given the very small size of the UK's AD sector at the time, and the paucity of information available, a higher value (0.25 l/gVS) based on a very limited number of samples was adopted instead. Sewage sludge was also considered as a comparator and, if adopted, would have led to much lower RBP limit.

It follows from the above that the environmental regulator regarded the evidence provided in the original SU/OU/WRc consortium's report sufficient to support the setting of the current threshold.

3. Selection of a more appropriate virgin comparator

As highlighted in the Environment Agency's *Notes on the RBP Test and Alternatives* issued in July 2013, cattle slurry was selected as the virgin comparator since this is considered to have undergone a 'natural' anaerobic digestion process.

[12] Walker M., Banks, C., Heaven S., and Frederickson J, 2010. Residual biogas potential test for digestates. Development and evaluation of a method for testing the residual biogas potential of digestates. Sponsored by WRAP.

The AD industry representatives on the PAS 110 Steering Group consider that this is not the correct comparator for digestates that are based on food wastes and that pig slurry would be a more appropriate virgin comparator. This is because pig slurries are much more similar in their physical form and nutrient content to food-based digestates than cow slurries. This has been confirmed by Prof. Brian Chambers FACTS/0646 (ADAS) (personal communication):

'*There is no question that pig slurries are more similar to food-based digestates than cattle slurries. They are more similar in terms of physical form and nutrient content (particularly readily available nitrogen). It is for this reason data related to pig slurries are presently used as a surrogate for food-based digestates in nutrient planning software, such as MANNER-NPK and WRAP guidance on "Using Quality Anaerobic Digestate to Benefit Crops" (page 6).*'

The charts shown below, which illustrate some of the results from DC-Agri project[13] (field experiments for quality digestate and compost in agriculture and field horticulture, see http://www.wrap.org.uk/content/digestate-compost-agriculture for more information), confirm that, from the point of view of the nutrient content (total nitrogen and readily available nitrogen), food based digestates are much more similar to pig slurries than cow slurries.

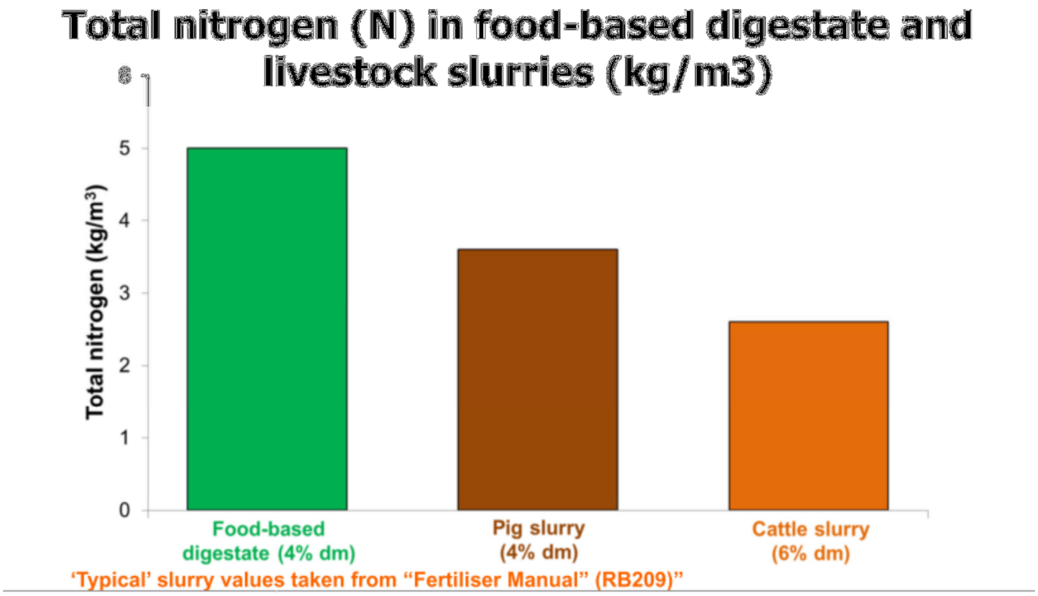

Figure 1. Total nitrogen in food-based digestate and livestock slurries

[13] DC-Agri project is a four year research project looking at the use of quality anaerobic digestate (biofertiliser) and compost in agriculture, integrated with an extensive knowledge exchange network. The project is funded jointly by Defra, WRAP, WRAP Cymru and Zero Waste Scotland.

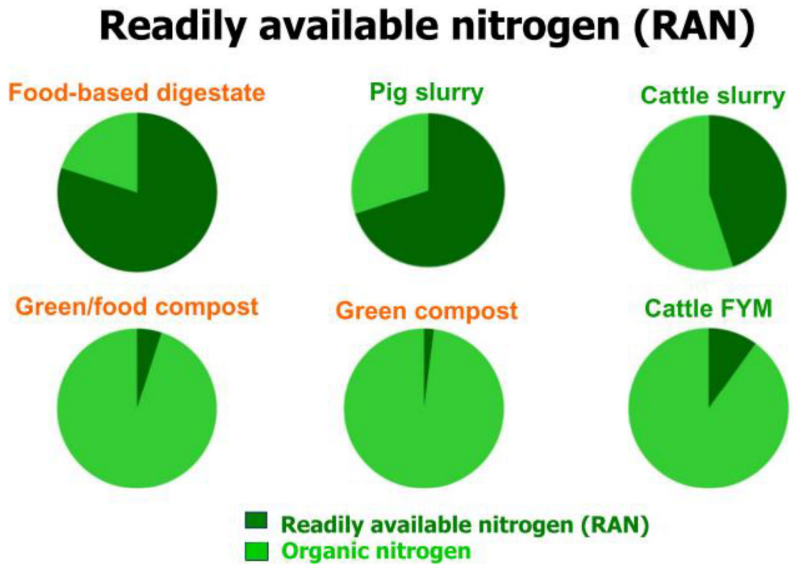

Figure 2. Readily available nitrogen in food-based digestate and livestock

Revision of the existing RBP limit level

WRAP-supported work[14], carried out subsequent to the original test method development, tested a number of similar materials including five cow slurries, one mixed cow & pig slurry, four pig slurries and one sewage sludge.

RBP values for the four pig slurries tested ranged between 0.501 and 0.876 l biogas / g VS.
In summary, the following RBP values for six pig slurry samples are now available from the original development work and the subsequent WRAP-supported work.

Table 1. RBP values for six pig slurry samples	
Sample	**RBP results[5] (l biogas/g VS)**
Pig slurry 1	0.260
Pig slurry 2	0.140
Pig slurry 3	0.501
Pig slurry 4	0.638
Pig slurry 5	0.638
Pig slurry 6	0.876

[15]

5. Testing RBP levels on whole digestate only

Feedback from the Open University and NRM is that the RBP should not be tested on separated liquors, particularly the very diluted ones (i.e. those with a very low dry matter content) as these have very low volatile solids content which can lead to distorted values and test failures), given how the RBP result is expressed (l biogas / g VS).

[14] http://www.wrapcymru.org.uk/sites/files/wrap/Digestate%20odour%20management%20%20Cymru.pdf
[15] Note that the source and type of pig slurries used for WRAP supported development work and subsequent work are unknown.

According to the OU, it is feasible to perform the test on separated digestate fibre fractions. These are more likely to pass the RBP level test as they contain high contents of volatile solids, some of which are typically recalcitrant.

However, the latest Southampton University R&D report on the RBP[16] recommends that, given the purpose of the RBP, the test is only applied to whole digestate.

6. Sampling point

AD industry representatives are happy to retain the current sampling approach, which requires the digestate to be sampled at the point of dispatch, after full treatment. This is because we consider that digestate should be sampled in the form in which it will be delivered to the customer.

For AD plants that are separating the whole digestate, it is proposed that samples for the RBP test be taken just prior to separating whole digestate into separate fractions.

7. RBP results related to BCS digestates

The data collected on the RBP test results for digestates were courtesy of the BCS and were kindly provided by NRM (the only lab appointed under the BCS).
The original dataset included 151 samples from 21 operators that are currently certified to PAS 110 or working towards certification. Only two of the operators registered on the BCS refused to disclose their data.

Contextual information about the samples was provided by all the operators e.g. when the AD plant start-up phase finished, the plant average retention time, and the point of sampling. This led to the removal of 35 samples that were obtained during the AD plants start-up phase and, thus, were not considered representative of digestate produced by a plant operating under stable conditions.

The **116** samples left included:

- **72** samples of whole digestate, of which **64** were from food waste only
- **21** samples of separated liquor
- **23** samples of separated fibre

Based on the recommendations from Southampton University, RBP should only be tested on whole digestates. Thus we have shown below basic statistics derived from the 72 samples of whole digestates in the available dataset and on the 64 food waste only digestates included in the same dataset[17]. These include RBP results on digestates from 13 operators. Results from 4 out of the 13 operators showed occasional or consistent RBP failures. Digestate from a further 3 operators showed occasional or regular failures for separated liquors and separated fibre fractions.

Data from different operators have not been directly assessed or compared, and the influence of operators' results on the outcome of the statistical assessment has not been performed.
The normal distribution of the data obtained was confirmed by preparing a frequency histogram and conducting a Kolmogorov-Smirnov test for normality on it.

[16] Charles J. Banks, Dr Sonia Heaven, Dr Yue Zhang, Dr Melanie Sapp
[17] Data from different operators have not been directly assessed or compared, and the influence of operators' results on the outcome of the statistical assessment has not been performed.

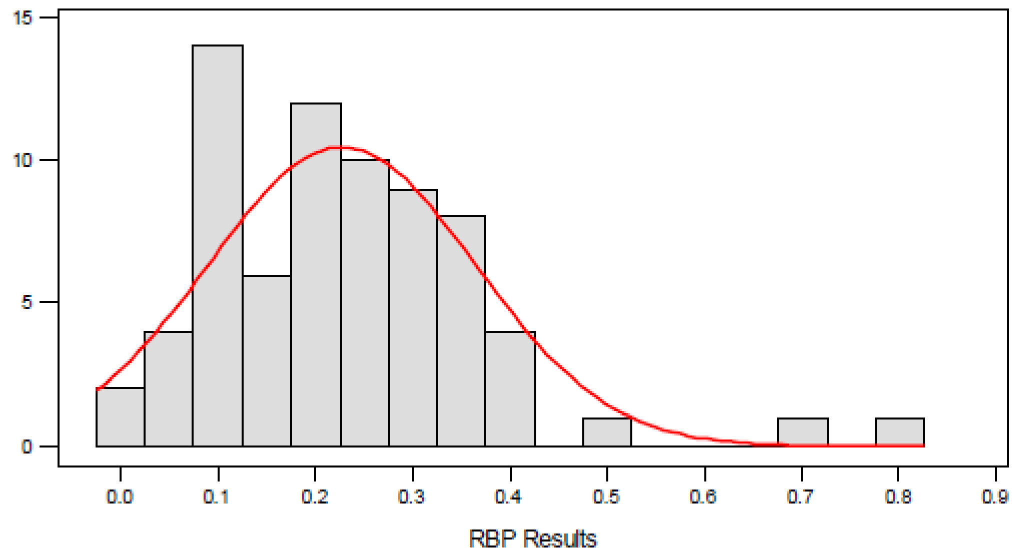

Figure 3. Histogram of RBP results, with normal curve

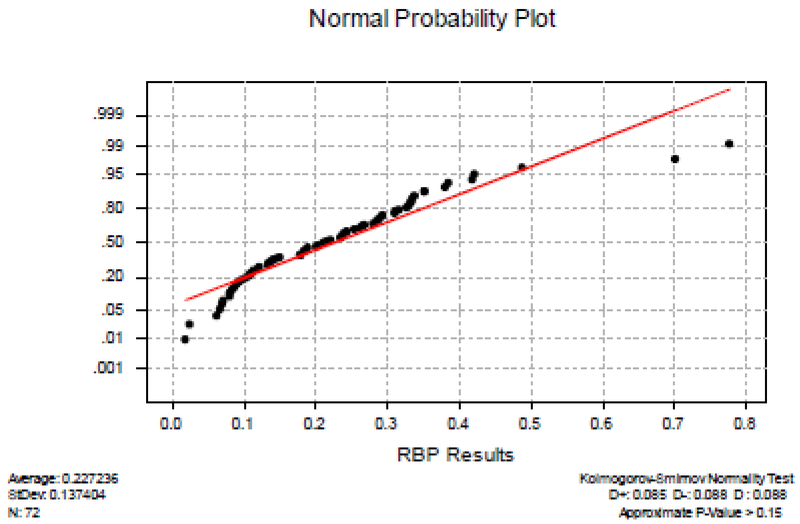

Figure 4. Normality probability plot on RBP results from BCS digestates

The histogram and the normality probability plot above confirm that the distribution is not significantly different from normal.

Table 2 below show basic statistics carried out on the **72** samples of whole digestate and the **64** samples of whole digestates based on food waste only.

Table 2. Data on the failure rate of 72 samples of whole digestates and 64 samples of food-based only whole digestates which have been tested using the RBP test against the current PAS 110 limit.

Whole digestates (all samples)		Food-based only whole digestates
Statistical parameter	**RBP (l biogas/g VS)**	**RBP (l biogas/g VS)**
Test failure rate (%)	**40.3**	**45.3**
Mean of sampling distribution	0.227	0.240
Upper confidence limit (95%)	0.259	0.274

Lower confidence limit (95%)	0.195	0.206
Standard Deviation (SD)	0.137	0.140
Median of sampling distribution	0.215	0.238
75th Percentile	0.298	0.313
90th percentile	0.352	**0.372**
95th percentile	0.419	**0.421**
Mean + 1 SD	0.365	**0.380**
Mean + 1.96 SD	0.497	**0.514**
N samples	72	64

From the above statistics we can deduce few key points:

- The current failure rate when considering the existing RBP limit level of 0.25 l biogas/g VS is high (40 % for the full dataset of whole digestates and 45% for the dataset of whole digestates based on food waste only), even despite the fact that these AD plants are operating under stable conditions and are either working toward certification or are already certified. This implies these plants should have an appropriate quality management system and a HACCP plan in place aligned to the requirements of PAS 110 to ensure the production of a quality digestate. In the case of certified plants, this quality management system and HACCP plan has been audited by independent certification bodies and has proved to be effective.

- 90 - 95% of the samples would have passed the test if the limit had been set at approximately 0.4 l biogas/g VS.

- For both set of data (whole digestates and food-based only whole digestates), the 95th percentile is lower than most of the values reported for pig slurries. This clearly shows that digestates registered on the BCS can be recovered to a point that not only is comparable but it's much lower than the values reported for pig slurries.

- 98% of the values of the whole population in a normal distribution should lie within 1.96 times the standard deviation of the mean, namely between **0** and **0.5 l biogas/g VS**.

The data obtained from RBP testing has shown that 0.4 l biogas/g VS is a level that AD operators registered on the BCS can reasonably achieve, but even achieving that level remains challenging and that there may be occasional spikes measured at higher levels.

The AD operators present at the meeting pointed out that, as the gate fees continue to drop (as competition for feedstocks increases) and more and more local authorities require compliance with PAS 110 for the treatment of their wastes, it is in their interest to maximise biogas production and achieve compliance with PAS 110. Any AD operator that has invested the significant sums required, in most cases millions of pounds, considers it extremely unlikely that an operator would chose to put feedstocks through the system quickly as this would reduce the amount of biogas produced and, thus, reduce the main source of income for the operator.

8. Minimum sampling frequency proposed for validation and on-going compliance with regard to RBP

It is proposed that at least three samples be tested for RBP during validation, over a minimum period of 3 months, with a minimum interval of one month between consecutive samples. This is a change from the existing approach, based on which the interval between two consecutive samples is the average retention time of the plant. The new proposed approach should ensure that samples of digestate are taken sufficiently far apart in time to ensure that each sample represents a different portion of production. This is confirmed by the statistics shown in table 3, related to the RBP results from an AD plant with an average retention time of 55 days. The table compares the mean and standard deviation of RBP results from samples obtained at a monthly frequency and samples obtained every other month. The means and standard deviations of the sampling distributions suggest that there is no significant difference in the RBP results for this plant whether it is sampled on a monthly basis or every other month.

AD operators should be able to justify alternative sampling programmes (e.g. a number of samples higher than the three minimum required or a higher time interval between two consecutive samples) to reflect potential fluctuations in the input materials.

It is proposed that the frequency of sampling after validation (for checking on-going compliance with the RBP limit level) is retained from the current approach (2 samples per 12 months, not within 3 months of each other or sooner if and when a significant change occurs). It is proposed that the frequency is not increased in view of the considerable cost of the current RBP test (approximately £500 per sample). The cost would become prohibitive for small AD operators if the frequency was to be increased to more than two samples per year. The standard must be proportionate and cost-effective for all AD operators.

Table 3: RBP results from an AD plant with 55 days average retention time from samples obtained on a monthly and bi-monthly frequency			
Sampling month	RBP mean result - monthly frequency	RBP mean result: bimonthly sampling frequency	RBP mean result: bimonthly sampling frequency
Jun-13	0.317	0.317	
Jul-13	0.242		0.242
Aug-13	0.292	0.292	
Sep-13	0.268		0.268
Oct-12	0.352	0.352	
Nov-12	0.294		0.294
Dec-12	0.333	0.333	
Jan-13	0.280		0.280
Feb-13	0.238	0.238	
Mar-13	0.289		0.289
Apr-13	0.266	0.266	
May-13	0.312		0.312
Jun-13	0.355	0.355	
Jul-13	0.237		0.237
Aug-13	0.150	0.150	
No samples	15	8	7
Mean	0.282	0.288	0.275
Standard Deviation	0.053	0.069	0.027

9. Approach for evaluating compliance with the RBP limit level

With the current approach for evaluating compliance with PAS 110 minimum quality criteria, each portion of production sampled and tested for RBP is evaluated against the existing RBP limit level (0.25 l biogas / g VS). If the sample fails to comply with the limit, the impact is considerable:

- If the portion of production sampled is still on site (e.g. in the storage tank), any digestate mixed with the failed portion of production is non-conforming ('waste'), thus it needs to be either re-processed or spread under deployments as waste; under the HACCP approach, all digestate produced following the failed portion of production is also classed as non PAS 110 conforming (waste), until three consecutive passes for RBP have been re-gained[18]. Given that the RBP test results are often delivered by the laboratory up to 35 days after the sample was taken, it follows that the AD operator will have to store and deal with considerable amount of waste digestate that has been produced subsequently to the failed sampled portion.

[18] After validation, under clause 13.4 a re-test may be conducted after pumping more material into the tank from which the sample was taken. If this passes, this can be counted as the first of the three consecutive passes required.

- If the portion of production is no longer on site (e.g. it has already been dispatched to a customer), then the implications are even more severe, as the AD operator will have to inform his customers and the regulator of the failure and will have to obtain deployments retrospectively.

The main criticism with this approach is the severity of the impact of one failure on any one operator. We believe that these impacts are disproportionate to the actual implications of a failure, and have therefore proposed some alternative approaches.

Option 1

The first alternative approach that could be included in the PAS 110 is a rolling average approach, based on which compliance with the standard is evaluated on the basis of the arithmetic average calculated from a suitable number of samples. This would be a moving average, which is updated every time a new sample is tested for RBP.

Based on the considerations made in sections 4 and 7 above, we would suggest that an absolute maximum limit of 0.5 l biogas / g VS is set on a rolling average basis.

A rolling average approach should encourage more AD operators to try producing PAS 110 digestate, as AD operators perceive that the likelihood of having to obtain 'back-up' customers with Environmental Permits to landspread failed portions of production as waste is lower.
Such an approach is similar to that proposed by JRC-IPTS in the End of Waste proposals for composts and digestates.

Actions in the event of test failures:

- In the event that the arithmetic mean exceeds 0.5 l biogas / g VS, extra samples should be tested for the RBP until the rolling arithmetic mean returns to be within 0.5 l biogas / g VS.
- With regard to the latest sampled portion which caused the rolling average to exceed the limit, this should be dealt with as a non-conforming portion of production. Any other portion mixed with it would also be classed as non-conforming. Any portion subsequently produced is also non-conforming until the rolling average conforms to the limit level.

Option 2

This option is based on the current approach for evaluating compliance, but with the RBP limit level increased from 0.25 l biogas / g VS to 0.5 l biogas / g VS, based on the mean value of the six slurry samples tested for RBP.
Operators who are members of the AD Operators Working Group have a preference for Option 1.

The Biofertiliser Certification Scheme and other stakeholders in the PAS 110 Steering Group expressed a preference for Option 2 as it appears simpler and clearer.

10. Novel approaches

We strongly recommend that a clause is included in the revised PAS 110 which enables the Competent Authority to approve an alternative method (either test or calculation) provided that this achieves the Competent Authority's objectives. This approach is similar to that already allowed for demonstrating pathogen eradication under Notes 2 and 3, Annex A of PAS 110.

Proposed text of the clause: "the competent authority (e.g. the regulator) may approve an alternative method that achieves their objectives".

It should be made clear that the method need not be an equivalent to RBP, but should be derived from the stated objectives of the regulator. This clause should facilitate the addition of an alternative test method or other suitable approach (e.g. calculation method or a mass balance approach) in the future and the development of new tests which are quicker to conduct and cheaper than the current RBP. The RBP test is expensive and time consuming and the need for a replacement is widely supported by the industry; allowing for the development of an equivalent alternative has the advantage of avoiding a long wait for a full review of PAS110.

Finally, as highlighted below, it is crucial that the regulator clarifies the purpose of the RBP test or any alternative method. We therefore request that clear text explaining the purpose of requiring this test or an alternative method is provided by the regulator at the earliest opportunity.