Certificate No. OCC67391

Operator Competence Certificate

Title:

Mobile Plant for land spreading (land treatment resulting in benefit) (4MTMPL6)

This Certificate is awarded to

Richard George Street

Awarded: 21/12/2016

Authorised

WAMITAB Chief Executive Officer

CIWM Chief Executive Officer

The Chartered Institution of Wastes Management

This certificate is jointly awarded by WAMITAB and the Chartered Institution of Wastes Management (CIWM) and provides evidence to meet the Operator Competence requirements of the Environmental Permitting (EP) Regulations, which came into force on 6 April 2008.

00123142

+Agricultural Benefit Statement

Report Index

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1. Permit Details and Appropriate Technical Expertise

The following benefit statement has been written by Richard Street on behalf of Agrispread Ltd. (permit no. FB3606GC).

Relevant Qualifications & Experience include:

- FACTs Qualified – Basis registration no. R/FE/5689
- 7 Years' experience of waste to land recycling operations
- Land spreading of non-farm wastes course (3 day course – May 2010)
- BSc. (Hons) Environmental Management (University of Central Lancashire)

2. Land Details

The following benefit statement proposes to spread Ahlstrom Black Liquor to land. The land details are listed in Table 1, and the site map can be found in Figure 1.

Table 1: Farm and Land Details

Farm Name	Green Lane Farm
Farm Address and Postcode	Sealand, Cheshire, CH1 6HB
Farm NGR	SJ 35160 69083
Total Area to be Spread (hectares)	40.4

The waste will be spread directly to fields as there is no suitable storage at the land. Details of the operation are discussed in Section 4.

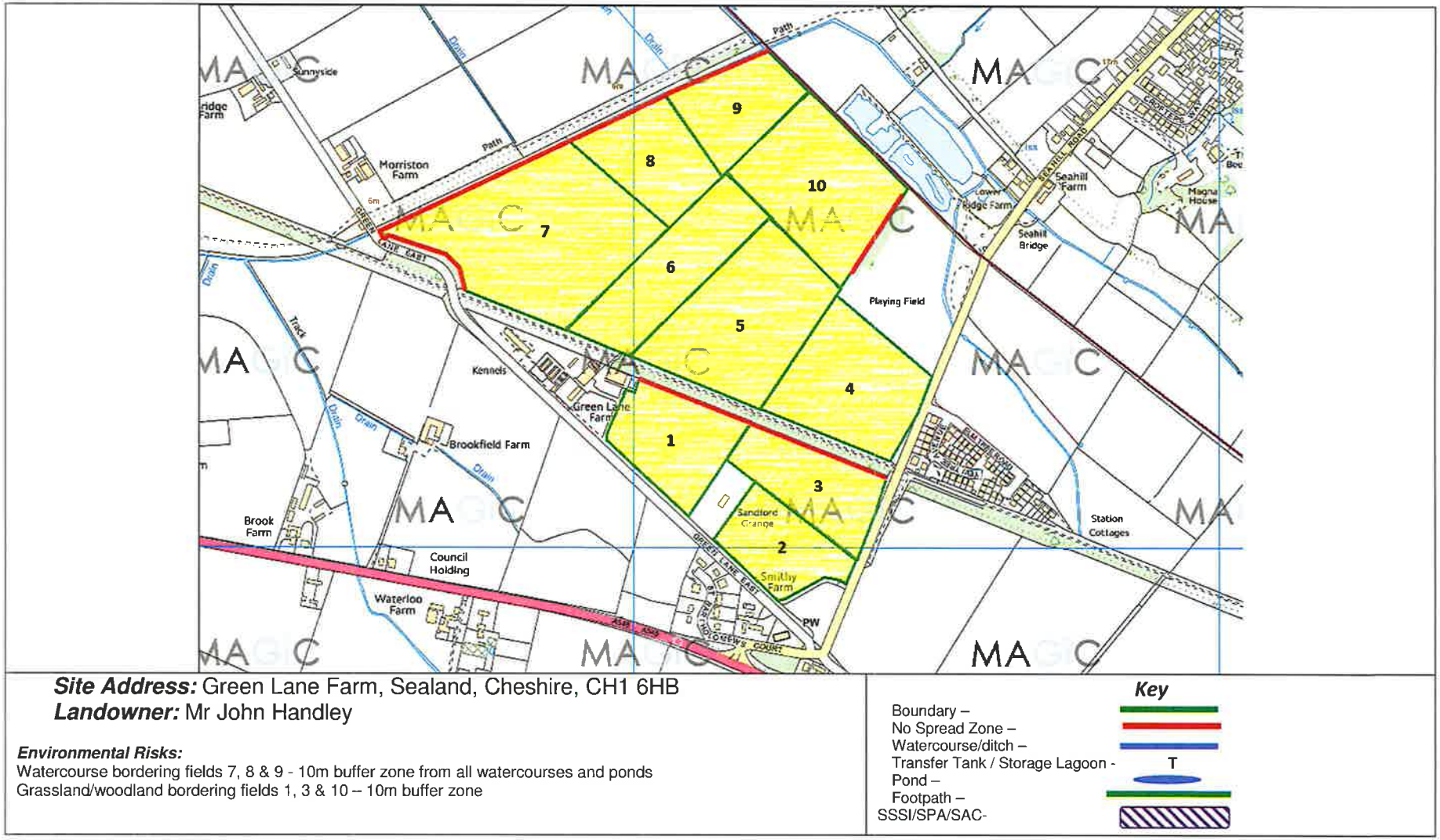

Figure 1: Site map including the fields to spread, receptors, storage (T), and spreading control measures

3. Waste Details

The waste details of Ahlstrom Black Liquor (listed as Northern Disposal Services on waste analysis) are displayed in Table 2.

Table 2: Waste Details

Waste Producer	Ahlstrom Chirnside Limited
Address of Waste Producer	Mt Sion Works, Mount Sion Rd, Radcliffe, Manchester, M26 3SB
EWC Code	03 03 11
Waste Description	Produced as a by-product of cellulose fibre extraction (sludge from on-site ETP other than 03 03 10)

Ahlstrom Black Liquor contains moderate levels of sulphur and potash, and trace levels of magnesium, phosphate and nitrogen. The waste has been analysed by NRM laboratories in August 2017 for nitrogen, phosphorous, potash, PTE's and other analysis such as FOGs and water soluble sulphur, and the waste analysis, and a waste evaluation, is attached in Appendix D. The waste is named Northern Disposal Services on the attached analysis.

4. Operational Details

The Ahlstrom will be delivered to the site by road tanker and off-loaded. The black liquor will be surface applied by umbilical supplied tractor mounted spreader bar or splash plate to reduce the risk of compaction across fields caused by the travelling weight, and due to the low application rate. In order to reduce the risk of crop scorch, applications of the liquor may be split, especially if spreading occurs during the summer months.

It is intended to spread Ahlstrom to arable fields before seedbed preparation. For this application, the waste is expected to be applied to maize fields (fields 1, 3, 4, 5) in March 2019; and winter wheat (fields 2 – 6 & 10) in October/November 2019. However, this may change due to farmer requirements and weather conditions.

5. Fields and Crop Requirement

Ahlstrom will be applied to all fields and so the crop requirements for all fields, as well as the field sizes and grid references, are displayed in Table 3. Fertiliser requirements are based on figures from the RB209 (9th edition). The magnesium recommendation for all fields is 0 kg/ha.

Table 3: Field Details and Crop Requirements (* denotes crop offtake)

Field	Size	Grid Reference	Current Crop	Next Crop	SNS	Expected Yield	Nitrogen	Phosphate	Potash
	ha					t/ha	kg/ha	kg/ha	kg/ha
1	3.0	SJ 35062 69188	Wheat	Maize	1	40	100	20	235
2	2.4	SJ 35247 69009	Wheat	W Wheat	1	8	220	95	145
3	2.8	SJ 35298 69117	Wheat	Maize	1	40	100	85	235
4	4.3	SJ 35374 69282	Barley	Maize	1	40	100	85	235
5	5.5	SJ 35192 69393	Barley	Maize	1	40	100	85	235
6	3.8	SJ 35057 69469	Maize	W Wheat	1	8	220	65	145
7	8.0	SJ 34839 69536	Maize	W Wheat	1	8	220	65	145
8	3.0	SJ 35035 69674	Maize	W Wheat	1	8	220	65	85
9	2.5	SJ 35177 69763	Maize	W Wheat	1	8	220	65	85
10	5.1	SJ 35320 69626	Maize	W Wheat	1	8	220	0 Off take 67	***0*** ***Off take 83***
Total	**40.4**								

The soil nitrogen supply (SNS) for all fields is 1.

6. NVZ Compliance

The site falls within an NVZ designated area, which is illustrated in Figure 2. The waste does not apply for the closed periods as Ahlstrom contains trace levels of nitrogen. The application rate of Ahlstrom will comply with crop requirement as no more than crop offtake of all nutrients will be applied to fields. In order to aid the landowner or farmer with their recording requirements, a post-notification of nutrients applied will be provided after spreading.

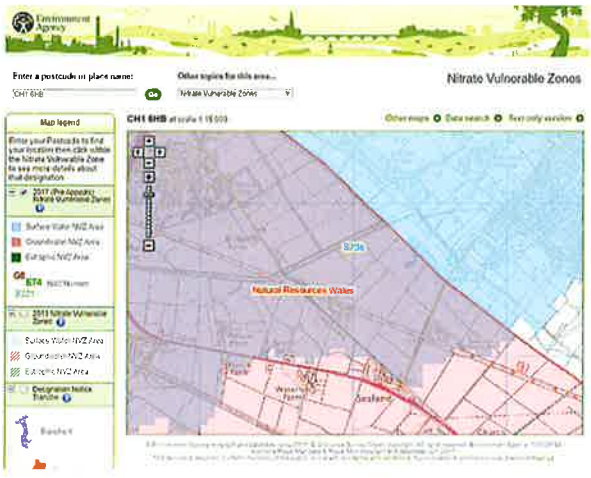

Figure 2: NVZ map for the land to be spread produced from the 'What's in my backyard' mapping service on the EA website (www.environment-agency.gov.uk).

Application rates are limited to a maximum of 250 kg total N/ha, and any other organic waste or manure applications have been accounted for. Previous nutrients applied to the fields within the last 12 months are listed in Table 4. The nutrients in Table 4 are total applied, and the availability of each can be taken from the standard figures in the RB209 (9th edition, section 2).

Table 4: Previous Nutrients Applied

Field	Waste Applied	Month Applied	Application Rate	Nitrogen	Phosphate	Potash
			t/ha	kg/ha	kg/ha	kg/ha
1	Ahlstrom & Biosolids	August & September 18	24 & 21	242	302	70
2	Ahlstrom	February 18	19	9	302	68
3	Ahlstrom	February 18	23	10	302	69
4	Ahlstrom	February 18	21	9	302	69
5	Ahlstrom	February 18	25	10	302	68
6	Ahlstrom & Biosolids	February & September 18	25 & 21	243	302	72
7	Ahlstrom & Biosolids	August & September 18	26 & 21	243	302	72
8	Ahlstrom & Biosolids	August & September 18	26 & 21	243	302	72
9	Ahlstrom & Biosolids	August & September 18	26 & 21	243	302	72
10	Ahlstrom & Biosolids	August & September 18	26 & 21	243	302	72

7. Benefits of The Operation

The Ahlstrom will be used to provide plant nutrients that will replace a percentage of the fertiliser that the farmer would normally apply to their crop. The waste will primarily be used as an alternative to potash fertiliser. The liquor will also provide benefit through the addition of organic matter and trace elements. A full waste assessment is attached in Appendix D, and a summary of Ahlstrom can be found in Table 5.

Table 5: Summary of Ahlstrom Nutrients and Application Rate

Waste	Application Rate	Nitrogen		Phosphate		Potash	
	t/ha	(total)	(available) 30%	(total)	(available) 50%	(total)	(available) 90%
Fields 1-7	26	10	3.5	0.1	0.05	100	90
Fields 8-10	21	8.1	2.8	0.1	0.0	80.8	72.7

Nitrogen

The waste analysis shows that the ammoniacal and nitrate nitrogen in the waste is relatively low; indicating that only a small proportion of nitrogen will be available immediately. The

remaining total nitrogen applied will become available to the crop through mineralisation throughout following seasons. The rate of nitrogen release will be affected by several factors including climate, timing and method of application, and soil type.

Phosphorus

Ahlstrom contains trace levels of phosphorus, and at the proposed application rate of 26t/ha will apply trace amounts of phosphate (<1kg/ha). The landowner/farmer should look to reduce the P index, for fields with P indexes of 3, over the coming seasons.

Potash

The waste applied will not meet the crop requirements for potash for all fields but it will allow the landowner/farmer to considerably reduce the amount of chemical fertiliser required to meet the crop need. The application of Ahlstrom at 26 t/ha will provide nutrients at or below crop requirement or offtake, and will not result in an increase in soil nutrient reserves.

Organic Matter

The Ahlstrom waste will also provide a small increase in soil organic matter. This can help to improve soil structure and water, and nutrient holding capacity.

Soils

Additionally, full soil analysis of the proposed fields to be spread has been attached in Appendix C, and a summary table has been included in Table 6.

Table 6: Summary of soil pH and major nutrients for the fields to be spread

Field	Soil pH	Phosphate		Potash		Magnesium		Soil Type
		mg/l	Index	mg/l	Index	mg/l	Index	
1	7.9	29.6	3	36.7	0	43.0	1	Medium Loam
2	7.8	11.4	1	30.0	0	22.4	0	Medium Loam
3	8.2	11.2	1	35.0	0	21.4	0	Medium Loam
4	8.1	13.8	1	34.7	0	29.8	1	Medium Loam
5	8.1	14.0	1	28.0	0	28.6	1	Medium Loam
6	7.8	17.6	2	54.8	0	27.5	1	Medium Loam
7	8.2	18.4	2	55.6	0	26.8	1	Medium Loam
8	8.1	22.6	2	140	2-	19.8	0	Medium Loam
9	8.2	20.8	2	124	2-	20.4	0	Medium Loam
10	7.8	28.4	3	314	3	24.0	0	Medium Loam

The soils were sampled in September 2017 in accordance with the sampling procedures described in the RB209 (9th Edition). Analysis was carried out by NRM laboratories for pH, major plant nutrients, and potentially toxic elements (PTEs) described in the Sludge (Use in Agriculture) Regulations.

Soils were found to be medium loam as categorised in accordance with RB209 (9th edition) as mineral soils for crop recommendations.

Soil pH ranges from 7.8 and 8.2, and are above the target value, although it shouldn't affect crop performance. Soil P index's range from 1 to 3, and the soils are generally at or below the guideline target index of 2. Soil K levels ranged from index 0 to 3 and are generally below the target index level of 2-. The magnesium index for all fields was satisfactory. PTE concentrations for all fields is low and within the typical range of uncontaminated soil.

8. Potential Negative Impacts

There are no known, or expected, elevated levels of PTEs within the Ahlstrom waste. However, the waste does contains high levels of sodium and sulphur, and justification in this regard is explained in this section. Additionally, a report by '*4Recycling*' prepared for '*Northern Disposal Services*' on the '*Assessment of suitable application rates for the recycling of Ahlstrom Black Liquor to agricultural soils*' has been appended in Appendix E, which further details the sulphur and sodium content.

Sulphur

The sulphur will be less likely to leach as it will be bound to the organic matter in the soil as the soil type is medium loam. This is because the majority of the sulphur present is in the form of lignosulphates, which are organically bound to the soil. These are stable compounds that promote soil aggregation and thus have been used as soil conditioners.

The levels of sulphur will be monitored over the coming seasons to ensure that a continued build-up of sulphur will not have a detrimental impact on the environment.

Sodium

The Ahlstrom analysis has an elevated conductivity caused by the presence of soluble salts, in particular sodium. If applied in very dry soil conditions, particularly on light textured soils, this might lead to a risk of temporary scorch, in particular grass, and might affect germination of small seeded crops. Therefore, care will be taken to ensure that Ahlstrom is applied to short, cut or grazed grass and to soils that aren't too dry or light textured.

This will be mitigated by the soil types at this farm which are of medium loams and the high rainfall in this area (<700mm/yr). Previous detailed plant growth trials using this waste have shown that electrical conductivity of the soil will return to normal after a period of 10-12 weeks of application and that conductivity or soil structural instability is unlikely to be an issue when applying this waste at 26t/ha.

Site Hazards

Hazards have been identified on the site plan in Figure 1 and relevant control measures and buffer zones have been identified. Operations are to be carried out in accordance with the company generic risk assessment for landspreading, which will reduce the impacts of the operation on the receiving soil.

Odour and Noise Control

The waste has the potential to cause odour however it is unlikely to cause nuisance odour issues. The operation will be carried out in accordance within normal agricultural hours to minimise the risk of odour and noise complaints.

9. Sensitive Receptors

There are a number of properties within 500m of the fields proposed to be spread. Odour and noise will be controlled, as detailed in section 8, in order to minimise the disruption caused to residents.

There are no footpaths or tracks crossing the fields to be spread, and no boreholes, wells or springs have been identified within the spreading area.

The site is within a flood prone area and the land is outside a ground water protection zone (Figure 3). The waste will be spread in appropriate conditions with weather and field conditions continuously examined.

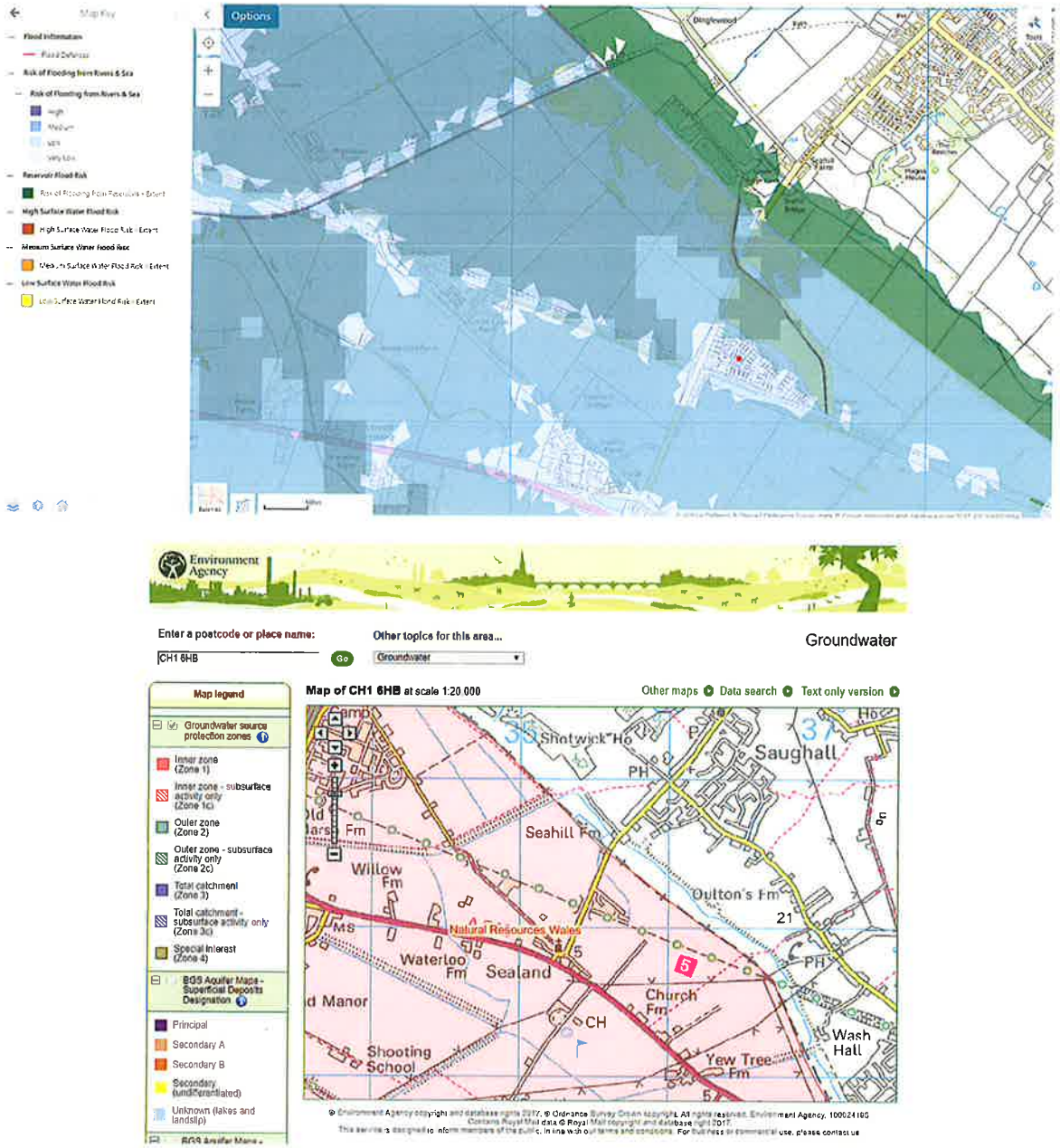

Figure 3: Maps of flood prone areas and ground water protection zones of the land to be spread. These were obtained from the NRW website (naturalresources.wales/evidence-and-

data/maps/long-term-flood-risk) and 'What's in my backyard' (www.environment-agency.gov.uk) respectively.

The site is not within 500m of a statutory designated environmentally sensitive area as defined by Magic Maps (magic.gov.uk).

10. Contingency Planning

To cover machinery breakdown, replacement machinery is available or can be hired from suppliers and mobile mechanics are available to attend sites. All machinery is regularly serviced.

There is sufficient trained staff to maintain sickness and holiday cover.

Spreading operations will not be carried out when there are adverse weather conditions that are likely to interfere with the operation. These conditions include; heavy rain, or during periods of heavy snow or frozen ground as defined in the Code of Good Agricultural Practice (COGAP).

SOIL CHEMICAL ANALYSIS REPORT FOR FIELD - 1

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JOHN HANDLEY
GREEN LANE FARM
CH1 6HB

SOIL

Date Received	11-SEP-2017
Date Reported	15-SEP-2017

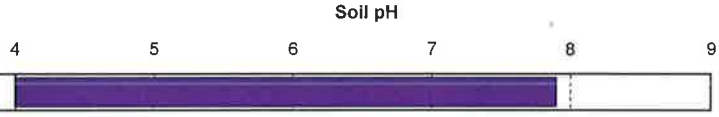
Laboratory References

Report Number	73265
Sample Number	355217

ANALYTICAL RESULTS *on 'dry matter' basis.*

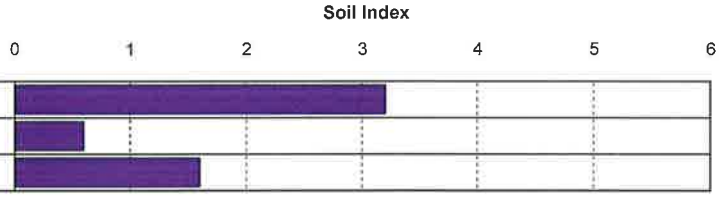
pH (1)

Determinand	Result
Soil pH	7.9



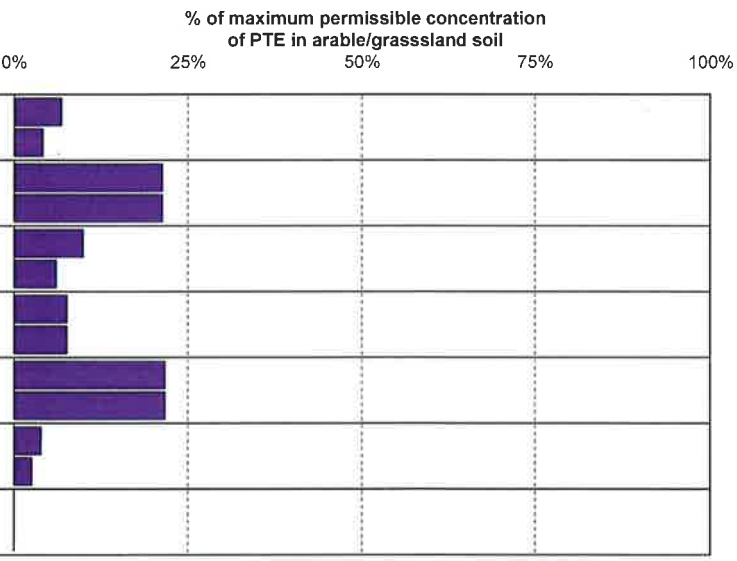
Soil Nutrients (1)

Determinand	Result mg/litre	Soil Index
Soil Phosphorus as P	29.6	3
Soil Potassium as K	36.7	0
Soil Magnesium as Mg	43.0	1



Potentially Toxic Elements (2)

Determinand	Result mg/kg		Maximum mg/kg
Total Copper as Cu	13.7	Arable	200
		Grassland	330
Total Zinc as Zn	64.1	Arable	300
		Grassland	300
Total Nickel as Ni	11.0	Arable	110
		Grassland	180
Total Cadmium as Cd	0.23	Arable	3
		Grassland	3
Total Lead as Pb	65.2	Arable	300
		Grassland	300
Total Chromium as Cr	15.7	Arable	400
		Grassland	600
Total Mercury as Hg	<0.2	Arable	1
		Grassland	1.5



(1) Recommendations for liming and fertiliser should be obtained from Defra's Fertiliser Manual (RB209). The analytical methods used are as described in Defra's RB427.

(2) Concentration of Potentially Toxic Elements (PTE, commonly referred to as 'heavy metals') are in mg/kg dry soil. The maximum and the percentage of this maximum permissible concentration of PTE in soil are derived from the values in Defra's Code of Practice for Agricultural Use of Sewage Sludge (England & Wales) 1996. If applying organic manures to this soil it is important to ensure the soil is managed with a pH no less than 5.0, and that the PTE maximum values are not exceeded following the application. For soil where the pH value is less than 5.2, a FACTS Qualified Adviser should be consulted. Further details are provided in the Sludge Code.

Released by *Darren Whitbread* Date *15/09/17*

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SOIL CHEMICAL ANALYSIS REPORT FOR FIELD - 2

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SOIL

Date Received	11-SEP-2017
Date Reported	15-SEP-2017

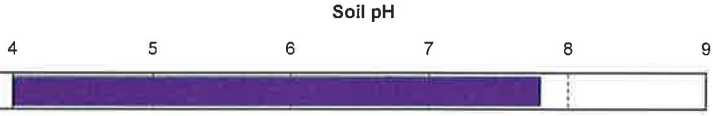
Laboratory References

Report Number	73265
Sample Number	355218

ANALYTICAL RESULTS *on 'dry matter' basis.*

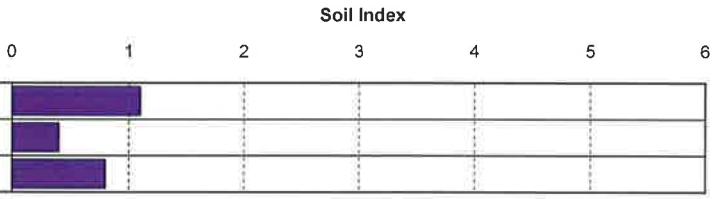
pH (1)

Determinand	Result
Soil pH	7.8



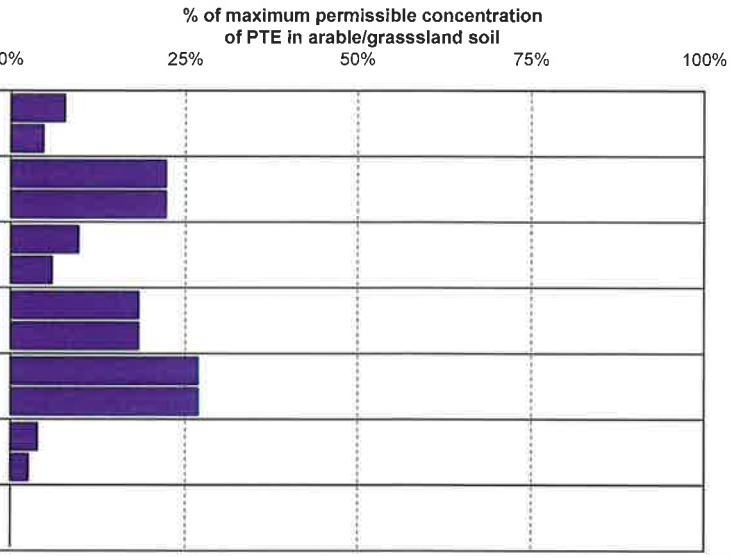
Soil Nutrients (1)

Determinand	Result mg/litre	Soil Index
Soil Phosphorus as P	11.4	1
Soil Potassium as K	30.0	0
Soil Magnesium as Mg	22.4	0



Potentially Toxic Elements (2)

Determinand	Result mg/kg		Maximum mg/kg
Total Copper as Cu	15.5	Arable	200
		Grassland	330
Total Zinc as Zn	66.8	Arable	300
		Grassland	300
Total Nickel as Ni	10.7	Arable	110
		Grassland	180
Total Cadmium as Cd	0.55	Arable	3
		Grassland	3
Total Lead as Pb	80.8	Arable	300
		Grassland	300
Total Chromium as Cr	15.6	Arable	400
		Grassland	600
Total Mercury as Hg	<0.2	Arable	1
		Grassland	1.5



(1) Recommendations for liming and fertiliser should be obtained from Defra's Fertiliser Manual (RB209). The analytical methods used are as described in Defra's RB427.

(2) Concentration of Potentially Toxic Elements (PTE, commonly referred to as 'heavy metals') are in mg/kg dry soil. The maximum and the percentage of this maximum permissible concentration of PTE in soil are derived from the values in Defra's Code of Practice for Agricultural Use of Sewage Sludge (England & Wales) 1996. If applying organic manures to this soil it is important to ensure the soil is managed with a pH no less than 5.0, and that the PTE maximum values are not exceeded following the application. For soil where the pH value is less than 5.2, a FACTS Qualified Adviser should be consulted. Further details are provided in the Sludge Code.

Released by *Darren Whitbread* Date *15/09/17*

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SOIL CHEMICAL ANALYSIS REPORT FOR FIELD - 3

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SOIL

Date Received	11-SEP-2017
Date Reported	15-SEP-2017

Laboratory References

Report Number	73265
Sample Number	355219

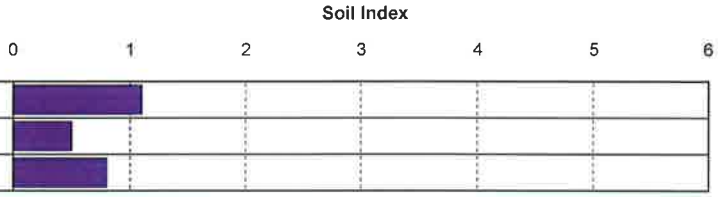
ANALYTICAL RESULTS *on 'dry matter' basis.*

pH (1)

Determinand	Result
Soil pH	8.2

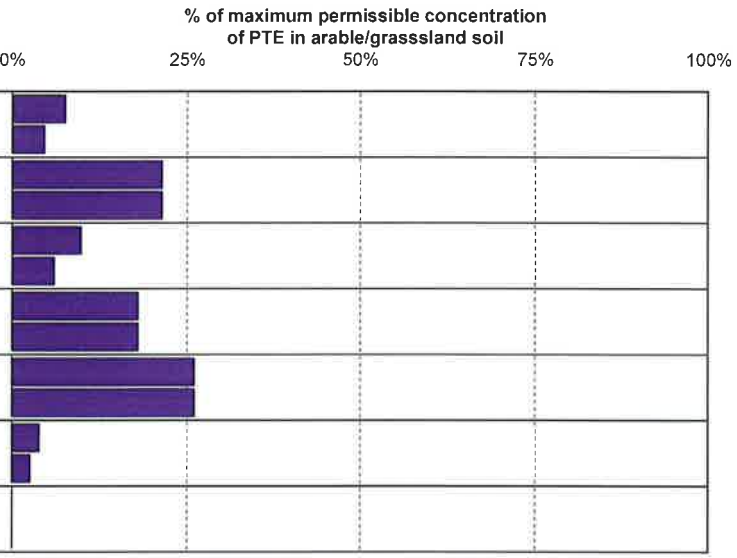
Soil Nutrients (1)

Determinand	Result mg/litre	Soil Index
Soil Phosphorus as P	11.2	1
Soil Potassium as K	35.0	0
Soil Magnesium as Mg	21.4	0



Potentially Toxic Elements (2)

Determinand	Result mg/kg		Maximum mg/kg
Total Copper as Cu	15.1	Arable	200
		Grassland	330
Total Zinc as Zn	64.3	Arable	300
		Grassland	300
Total Nickel as Ni	10.8	Arable	110
		Grassland	180
Total Cadmium as Cd	0.54	Arable	3
		Grassland	3
Total Lead as Pb	78.1	Arable	300
		Grassland	300
Total Chromium as Cr	15.5	Arable	400
		Grassland	600
Total Mercury as Hg	<0.2	Arable	1
		Grassland	1.5



(1) Recommendations for liming and fertiliser should be obtained from Defra's Fertiliser Manual (RB209). The analytical methods used are as described in Defra's RB427.

(2) Concentration of Potentially Toxic Elements (PTE, commonly referred to as 'heavy metals') are in mg/kg dry soil. The maximum and the percentage of this maximum permissible concentration of PTE in soil are derived from the values in Defra's Code of Practice for Agricultural Use of Sewage Sludge (England & Wales) 1996. If applying organic manures to this soil it is important to ensure the soil is managed with a pH no less than 5.0, and that the PTE maximum values are not exceeded following the application. For soil where the pH value is less than 5.2, a FACTS Qualified Adviser should be consulted. Further details are provided in the Sludge Code.

Released by ..... *Darren Whitbread* Date *15/09/17*

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SOIL CHEMICAL ANALYSIS REPORT FOR FIELD - 4

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SOIL

Date Received	11-SEP-2017
Date Reported	15-SEP-2017

Laboratory References

Report Number	73265
Sample Number	355220

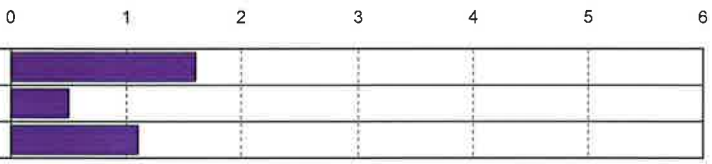
ANALYTICAL RESULTS *on 'dry matter' basis.*

pH (1)

Determinand	Result
Soil pH	8.1

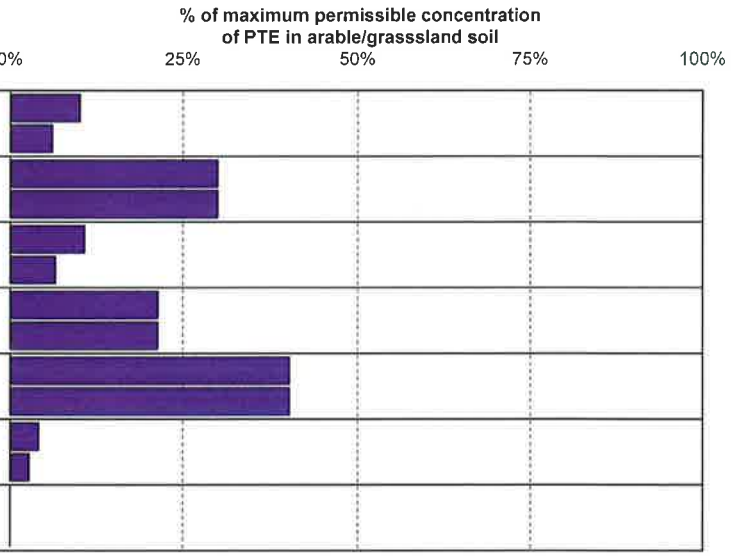
Soil Nutrients (1)

Determinand	Result mg/litre	Soil Index
Soil Phosphorus as P	13.8	1
Soil Potassium as K	34.7	0
Soil Magnesium as Mg	29.8	1



Potentially Toxic Elements (2)

Determinand	Result mg/kg		Maximum mg/kg
Total Copper as Cu	20.1	Arable	200
		Grassland	330
Total Zinc as Zn	90.1	Arable	300
		Grassland	300
Total Nickel as Ni	11.8	Arable	110
		Grassland	180
Total Cadmium as Cd	0.64	Arable	3
		Grassland	3
Total Lead as Pb	121	Arable	300
		Grassland	300
Total Chromium as Cr	16.6	Arable	400
		Grassland	600
Total Mercury as Hg	<0.2	Arable	1
		Grassland	1.5



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(2) Concentration of Potentially Toxic Elements (PTE, commonly referred to as 'heavy metals') are in mg/kg dry soil. The maximum and the percentage of this maximum permissible concentration of PTE in soil are derived from the values in Defra's Code of Practice for Agricultural Use of Sewage Sludge (England & Wales) 1996. If applying organic manures to this soil it is important to ensure the soil is managed with a pH no less than 5.0, and that the PTE maximum values are not exceeded following the application. For soil where the pH value is less than 5.2, a FACTS Qualified Adviser should be consulted. Further details are provided in the Sludge Code.

Released by *Darren Whitbread* Date *15/09/17*

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SOIL CHEMICAL ANALYSIS REPORT FOR FIELD - 5

MR ROB PIGGOTT
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LLANYPWLL
WREXHAM LL13 9YE

F990

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JOHN HANDLEY
GREEN LANE FARM
CH1 6HB

SOIL

Date Received	11-SEP-2017
Date Reported	15-SEP-2017

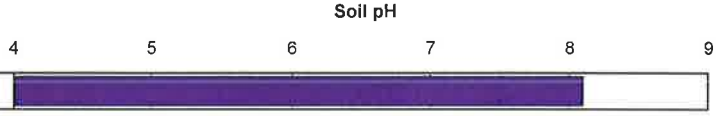
Laboratory References

Report Number	73265
Sample Number	355221

ANALYTICAL RESULTS *on 'dry matter' basis.*

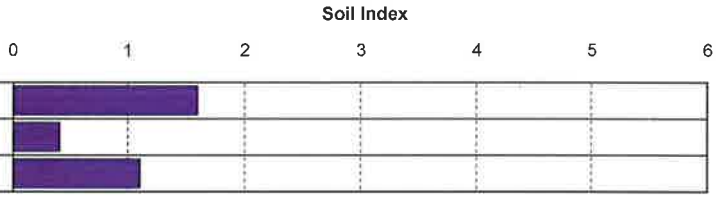
pH (1)

Determinand	Result
Soil pH	8.1



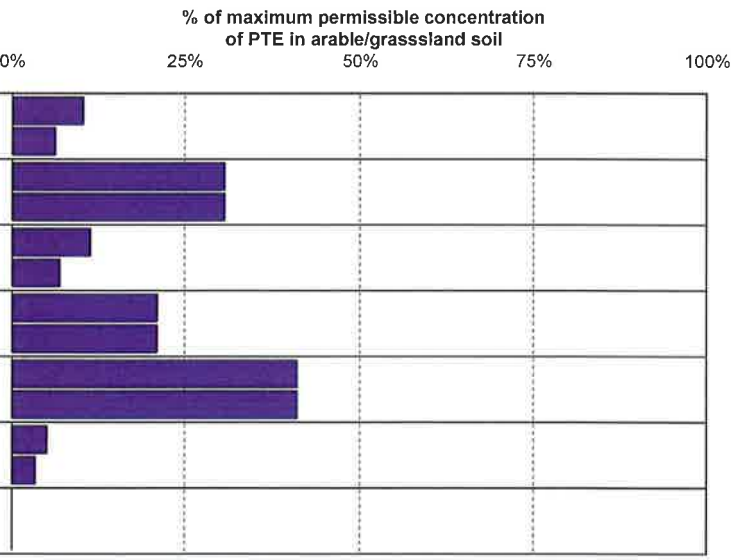
Soil Nutrients (1)

Determinand	Result mg/litre	Soil Index
Soil Phosphorus as P	14.0	1
Soil Potassium as K	28.0	0
Soil Magnesium as Mg	28.6	1



Potentially Toxic Elements (2)

Determinand	Result mg/kg		Maximum mg/kg
Total Copper as Cu	20.5	Arable	200
		Grassland	330
Total Zinc as Zn	92.0	Arable	300
		Grassland	300
Total Nickel as Ni	12.4	Arable	110
		Grassland	180
Total Cadmium as Cd	0.63	Arable	3
		Grassland	3
Total Lead as Pb	123	Arable	300
		Grassland	300
Total Chromium as Cr	20.2	Arable	400
		Grassland	600
Total Mercury as Hg	<0.2	Arable	1
		Grassland	1.5



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Released by ..... *Darren Whitbread* Date *15/09/17*

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SOIL CHEMICAL ANALYSIS REPORT FOR FIELD - 6

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JOHN HANDLEY
GREEN LANE FARM
CH1 6HB

SOIL

Date Received	11-SEP-2017
Date Reported	15-SEP-2017

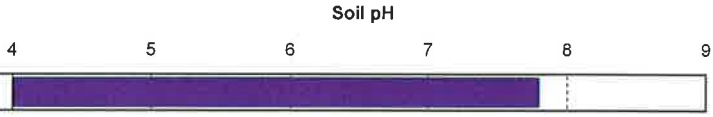
Laboratory References

Report Number	73265
Sample Number	355222

ANALYTICAL RESULTS *on 'dry matter' basis.*

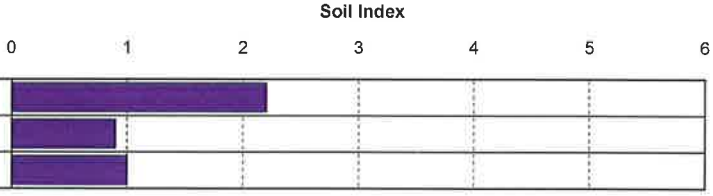
pH (1)

Determinand	Result
Soil pH	7.8



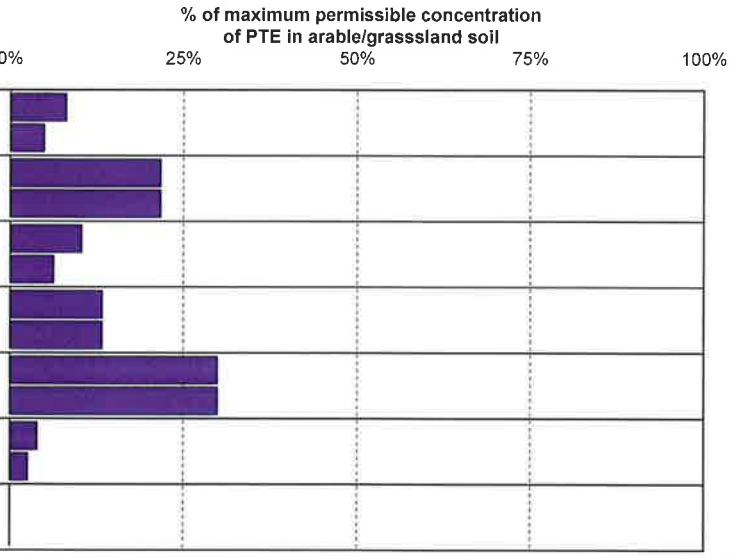
Soil Nutrients (1)

Determinand	Result mg/litre	Soil Index
Soil Phosphorus as P	17.6	2
Soil Potassium as K	54.8	0
Soil Magnesium as Mg	27.5	1



Potentially Toxic Elements (2)

Determinand	Result mg/kg		Maximum mg/kg
Total Copper as Cu	16.2	Arable	200
		Grassland	330
Total Zinc as Zn	65.1	Arable	300
		Grassland	300
Total Nickel as Ni	11.4	Arable	110
		Grassland	180
Total Cadmium as Cd	0.40	Arable	3
		Grassland	3
Total Lead as Pb	89.6	Arable	300
		Grassland	300
Total Chromium as Cr	15.8	Arable	400
		Grassland	600
Total Mercury as Hg	<0.2	Arable	1
		Grassland	1.5



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SOIL CHEMICAL ANALYSIS REPORT FOR FIELD - 7

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JOHN HANDLEY
GREEN LANE FARM
CH1 6HB

SOIL

Date Received	11-SEP-2017
Date Reported	15-SEP-2017

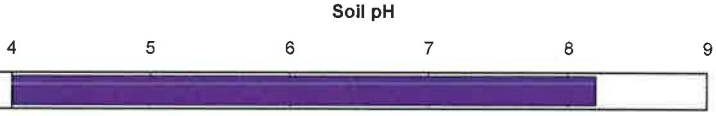
Laboratory References

Report Number	73265
Sample Number	355223

ANALYTICAL RESULTS *on 'dry matter' basis.*

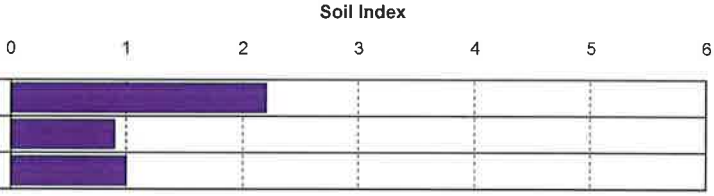
pH (1)

Determinand	Result
Soil pH	8.2



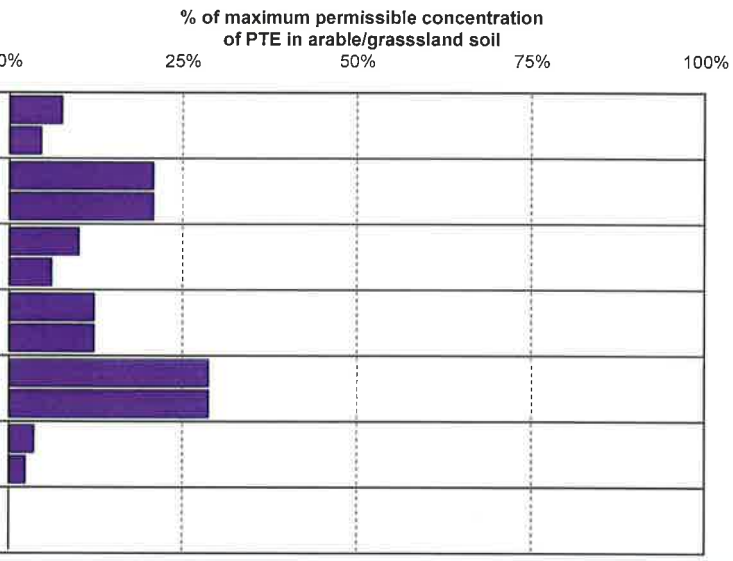
Soil Nutrients (1)

Determinand	Result mg/litre	Soil Index
Soil Phosphorus as P	18.4	2
Soil Potassium as K	55.6	0
Soil Magnesium as Mg	26.8	1



Potentially Toxic Elements (2)

Determinand	Result mg/kg		Maximum mg/kg
Total Copper as Cu	15.3	Arable	200
		Grassland	330
Total Zinc as Zn	62.4	Arable	300
		Grassland	300
Total Nickel as Ni	11.1	Arable	110
		Grassland	180
Total Cadmium as Cd	0.37	Arable	3
		Grassland	3
Total Lead as Pb	86.2	Arable	300
		Grassland	300
Total Chromium as Cr	14.6	Arable	400
		Grassland	600
Total Mercury as Hg	<0.2	Arable	1
		Grassland	1.5



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SOIL CHEMICAL ANALYSIS REPORT FOR FIELD - 8

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JOHN HANDLEY
GREEN LANE FARM
CH1 6HB

SOIL

Date Received	11-SEP-2017
Date Reported	15-SEP-2017

Laboratory References

Report Number	73265
Sample Number	355224

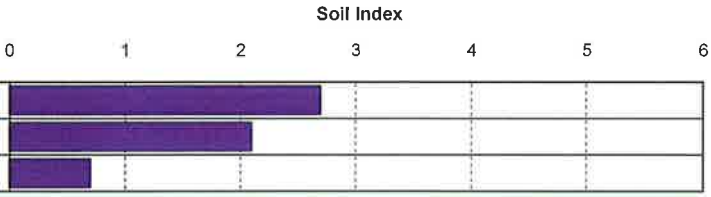
ANALYTICAL RESULTS *on 'dry matter' basis.*

pH (1)

Determinand	Result
Soil pH	8.1

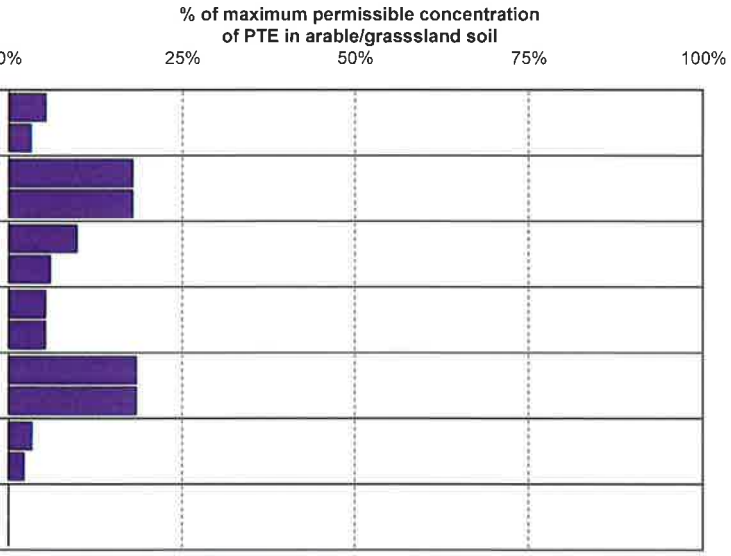
Soil Nutrients (1)

Determinand	Result mg/litre	Soil Index
Soil Phosphorus as P	22.6	2
Soil Potassium as K	140	2-
Soil Magnesium as Mg	19.8	0



Potentially Toxic Elements (2)

Determinand	Result mg/kg		Maximum mg/kg
Total Copper as Cu	10.6	Arable	200
		Grassland	330
Total Zinc as Zn	53.5	Arable	300
		Grassland	300
Total Nickel as Ni	10.8	Arable	110
		Grassland	180
Total Cadmium as Cd	0.16	Arable	3
		Grassland	3
Total Lead as Pb	55.2	Arable	300
		Grassland	300
Total Chromium as Cr	13.6	Arable	400
		Grassland	600
Total Mercury as Hg	<0.2	Arable	1
		Grassland	1.5



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SOIL CHEMICAL ANALYSIS REPORT FOR FIELD - 9

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JOHN HANDLEY
GREEN LANE FARM
CH1 6HB

SOIL

Date Received	11-SEP-2017
Date Reported	15-SEP-2017

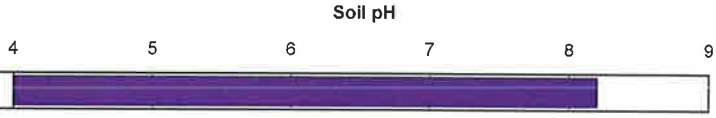
Laboratory References

Report Number	73265
Sample Number	355225

ANALYTICAL RESULTS *on 'dry matter' basis.*

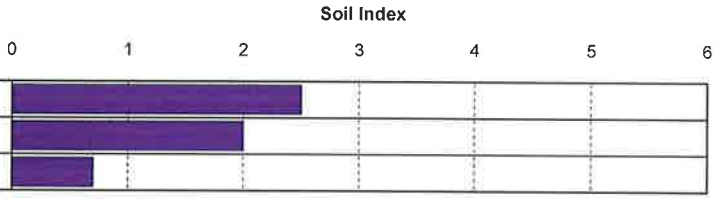
pH (1)

Determinand	Result
Soil pH	8.2



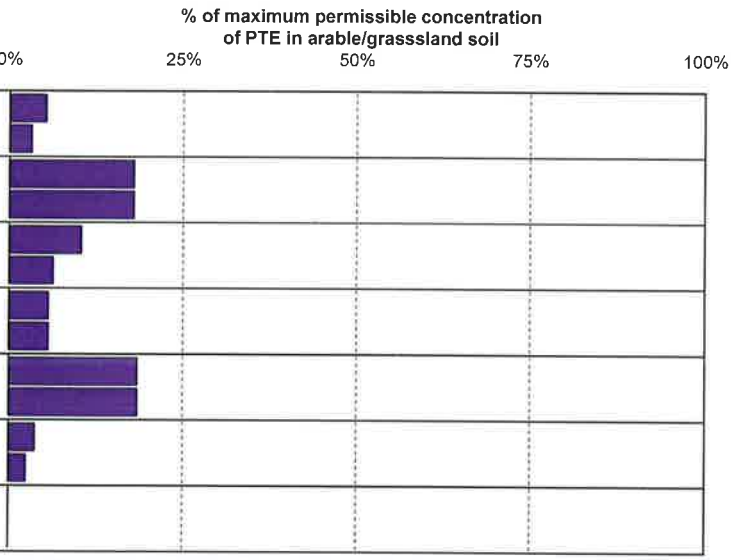
Soil Nutrients (1)

Determinand	Result mg/litre	Soil Index
Soil Phosphorus as P	20.8	2
Soil Potassium as K	124	2-
Soil Magnesium as Mg	20.4	0



Potentially Toxic Elements (2)

Determinand	Result mg/kg		Maximum mg/kg
Total Copper as Cu	10.6	Arable	200
		Grassland	330
Total Zinc as Zn	53.7	Arable	300
		Grassland	300
Total Nickel as Ni	11.4	Arable	110
		Grassland	180
Total Cadmium as Cd	0.17	Arable	3
		Grassland	3
Total Lead as Pb	55.3	Arable	300
		Grassland	300
Total Chromium as Cr	15.1	Arable	400
		Grassland	600
Total Mercury as Hg	<0.2	Arable	1
		Grassland	1.5



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SOIL CHEMICAL ANALYSIS REPORT FOR FIELD - 10

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JOHN HANDLEY
GREEN LANE FARM
CH1 6HB

SOIL

Date Received	11-SEP-2017
Date Reported	15-SEP-2017

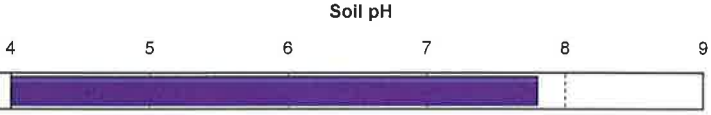
Laboratory References

Report Number	73265
Sample Number	355226

ANALYTICAL RESULTS *on 'dry matter' basis.*

pH (1)

Determinand	Result
Soil pH	7.8

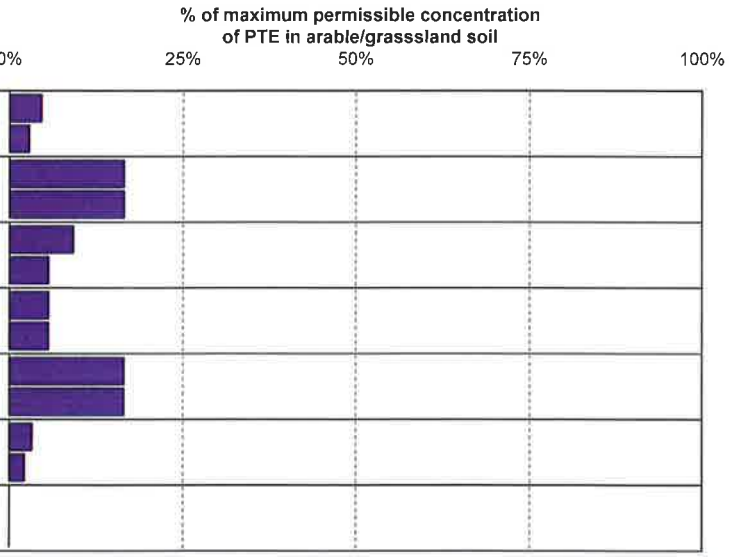


Soil Nutrients (1)

Determinand	Result mg/litre	Soil Index
Soil Phosphorus as P	28.4	3
Soil Potassium as K	314	3
Soil Magnesium as Mg	24.0	0

Potentially Toxic Elements (2)

Determinand	Result mg/kg		Maximum mg/kg
Total Copper as Cu	9.3	Arable	200
		Grassland	330
Total Zinc as Zn	49.8	Arable	300
		Grassland	300
Total Nickel as Ni	10.2	Arable	110
		Grassland	180
Total Cadmium as Cd	0.17	Arable	3
		Grassland	3
Total Lead as Pb	49.7	Arable	300
		Grassland	300
Total Chromium as Cr	13.1	Arable	400
		Grassland	600
Total Mercury as Hg	<0.2	Arable	1
		Grassland	1.5



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Released by *Darren Whitbread* Date *15/09/17*

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AHLSTROM

LIQUID WASTE

LIQUID WASTE

Sample Reference :

AHLSTROM

Sample Matrix : LIQUID WASTE

Laboratory References	
Report Number	27935
Sample Number	73778

Date Received	19-SEP-2018
Date Reported	26-SEP-2018

The sample submitted was of adequate size to complete all analysis requested.

The sample will be kept under refrigeration for at least 3 weeks.

ANALYTICAL RESULTS *on 'as received' basis.*

Determinand	Value	Units
Oven Dry Solids	13.0	%
Conductivity 1:6	11110	uS/cm
Total Nitrogen	<0.04	% w/w
Nitrate Nitrogen	<10	mg/kg
Ammonium Nitrogen	<50	mg/kg
Total Phosphorus (P)	<5	mg/kg
Total Potassium (K)	3200	mg/kg
Total Magnesium (Mg)	<10	mg/kg
Total Copper (Cu)	<0.2	mg/kg
Total Zinc (Zn)	0.69	mg/kg

Released by *Darren Whitbread* Date *26/09/18*

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AHLSTROM

LIQUID WASTE

LIQUID WASTE

Sample Reference :

AHLSTROM

Sample Matrix : LIQUID WASTE

Laboratory References	
Report Number	27935
Sample Number	73778

Date Received	19-SEP-2018
Date Reported	26-SEP-2018

The sample submitted was of adequate size to complete all analysis requested.

The sample will be kept under refrigeration for at least 3 weeks.

ANALYTICAL RESULTS *on 'as received' basis.*

Determinand	Value	Units
Total Sulphur (S)	12553	mg/kg
Total Calcium (Ca)	15.9	mg/kg
Total Lead (Pb)	<0.5	mg/kg
Total Cadmium (Cd)	<0.01	mg/kg
Total Mercury (Hg)	<0.05	mg/kg
Total Nickel (Ni)	<0.2	mg/kg
Total Chromium (Cr)	<0.2	mg/kg
Total Sodium (Na)	23904	mg/kg
pH 1:6 [Fresh]	9.31	
Organic Matter LOI	4.44	% w/w

Released by *Darren Whitbread* Date *26/09/18*

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AHLSTROM

LIQUID WASTE

LIQUID WASTE

Sample Reference :

AHLSTROM

Sample Matrix : LIQUID WASTE

Laboratory References	
Report Number	27935
Sample Number	73778

Date Received	19-SEP-2018
Date Reported	26-SEP-2018

The sample submitted was of adequate size to complete all analysis requested.

The sample will be kept under refrigeration for at least 3 weeks.

ANALYTICAL RESULTS *on 'as received' basis.*

Determinand	Value	Units
Water Soluble Magnesium	1.74	mg/kg
Water Soluble Phosphorus	1.70	mg/kg
Water Soluble Potassium	2913	mg/kg

Released by *Darren Whitbread* Date *26/09/18*

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Waste Producer	Ahlstrom Black Liquor
EWC code	03 03 11
Waste description	Black liquor from long fibre pulp
Laboratory	NRM Laboratories Ltd

Sample Ref: 73778

Ahlstrom Black Liquor was sampled in accordance with the standard sampling procedures in October 2017 and was analysis by NRM laboratories Ltd.

	Units	Result	Nutrients applied at 26t/ha
pH	-	9.31	-
Electrical conductivity	µS/cm	11400	-

The waste has low dry matter content and will apply 13% solids to the receiving soil. This will help improve soil structure and aid nutrient and water holding capacity.

The black liquor has a pH of 9.31 and no detrimental effects are anticipated from its application to most soils at the proposed spreading rate of 26t/ha.

A detailed report carried out in 2008 regarding the suitability of land application of the black liquor found no disbenefit from the application of black liquor and this is attached in Appendix E.

1. Major Plant Nutrients

	Unit	Result	Nutrients applied at 26t/ha
Nitrogen	kg/t	0	10
Phosphate	kg/t	0	0
Potash	kg/t	4	100
Magnesium	kg/t	0	0
Sulphur	kg/t	31.38	815.95

The liquor from the effluent treatment plant at Ahlstrom contains high levels of potash and sulphur with small quantities of phosphate, nitrogen and magnesium. Potash availability should be high and will be available for the next crop. Phosphate levels are low and less than 1kg/ha will be applied to the soil and following crop.

2. Potentially Toxic Elements (PTEs)

The waste was analysed for a range of PTEs as described in the Sludge (Use in Agriculture) Regulations. The analysis shows that the waste contains only trace elements of the majority of PTEs additions, and they fall well within the maximum permitted annual application limit. The table below shows the waste contribution of PTEs in kg/ha at the proposed application rate.

Application rate (t/ha)	Copper	Zinc	Lead	Cadmium	Mercury	Nickel	Chromium
26	0.01	0.02	0.01	0.0	0.0	0.01	0.01

3. Sodium

The total addition of sodium in any one application of the Ahlstrom Black liquor waste is 621.50kg/ha, which is higher than that recommended in agency guidance. However, the sodium will not all be immediately available as the extraction process makes use of the less available forms of sodium, which is likely to be bound within the lignin in the waste.

The loamy topsoil at the farm is at a lower risk of structural instability following addition of sodium than if they were a lighter texture. Structural instability is usually a feature associated with the addition of many tonnes of

sodium deposited within topsoil from seawater inundation, saline intrusion or from capillary rise and evaporation of saline water leading to salt in the upper layers. In extreme cases this can lead to de-flocculation of clay particles and structural instability, changes in soil-plant osmotic processes, induced drought stress and in extreme cases sodium toxicity. The sodium content has remained fairly stable since 2005 and with more than 9 years experience of spreading the black liquor; we are yet to see evidence of damage to the soil structure following an application of black liquor.

Bioassays carried out in 2000 applied black liquor at an application rate of 50t/ha and over 800kg/ha of total sodium was added to the soil. No detrimental effect to the soil structure was noted and after 12 weeks the elevated conductivity of the soil was 2165uS/cm, within the normal range for agricultural soils in the UK and within the limit for topsoil detailed in the BS3882. I would therefore conclude from this that the waste will not lead to unacceptable high longer term EC and sodium issues after application.

In addition, sodium is an essential element for grass herbage growth. Sodium fertilizers will not normally give extra grass yield but they will increase the Na content of grass which will improve the palatability of herbage and can reduce the chance of grass staggers. Sodium is also associated with a greater % of live herbage, higher D values and sugar content of grass. Research from Bangor University indicates that these effects increase milk output and % butterfat and may also have a small benefit on somatic cell count. Grass palatability and milk output increase at herbage sodium levels up to 0.5% in the dry matter.

4. Conductivity

While an application of Ahlstrom will temporarily elevate conductivity within the soils this does not automatically mean that it will cause crop scorch or lead structural damage after a receipt of the waste. It is largely dependent on soils type, weather and soil conditions. Many Chemical (Liquid & solid) fertiliser has an elevated conductivity far in excess of that measured in the Ahlstrom waste which will could lead to similar issues.

The conductivity within the waste is measured as the total of all of the salts it contains including chlorides, sulphates and other soluble oxides/compounds. The effects of conductivity are more pounced on soils that are lighter textured and also when soils are dry as the salts applied can increase the strength of the soil water solution and lead to induced drought stress. The fields are loamy textured and are in a heavy rainfall area so are low risk of induced drought stress.

5. Potential disbenefits

- The black liquor pH is 9.31 and no adverse effects are anticipated from its application to agricultural land.
- The level of PTEs applied are well within regulatory recommendations and will have no impact on the receiving soils or crops.
- Compaction of soils will be minimised by the use of an umbilical cord system and tractor mounted spreader.
- The black liquor does not have an offensive odour and is unlikely to cause a nuisance during normal spreading operations.
- Additions of sodium and conductivity which are discussed above.

6. Conclusion

The black liquor from the treatment plant at Ahlstrom provides agricultural benefit through the addition of major plant nutrients and will be used to reduce the requirement for chemical fertiliser. The liquor will supply additional benefit through the addition of organic matter to the receiving soil. Application rates will be reviewed to ensure soil and crop requirements are not exceeded following regular analysis of the waste.

The additions of sodium at the above applications rates fall within those that are recommended within previous assessments.

There should be no significant impacts on soil structural stability.

I would expect the electrical conductivity of the topsoil to initially rise after application but that it will return to normal within a matter of a few weeks, a feature no different to the effects of any fertiliser application.

The material has been recycled to land for a number of years and experience has shown that it can be applied without cause harm to the environment. There should be no disbenefit from the application when applied in accordance with the management plan and relevant current regulations.

COMMERCIAL IN CONFIDENCE

Assessment of suitable application rates for the recycling of Ahlstrom black liquor to agricultural soils

Prepared for:

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1. BACKGROUND

The Ahlstrom black liquor is produced as a by-product of cellulose fibre extraction from Abaca (Musa textilis). The cellulose is extracted with caustic soda and sodium sulphite at high temperature, high pH and high pressure. The lignin in the plant material is dissolved leaving behind the cellulose fibres. The lignin combines with the sulphite to form water-soluble sodium lignosulphonate which makes up the bulk of the liquor together with any surplus sulphite and sulphate. The remaining sulphite would be converted to either the lignosulphonate or sulphate.

Ahlstrom recycle the liquor to agricultural land and the Environment Agency have recently questioned technical aspects of this activity and responded with the following comments:-

> ***"With regards to your comments on sulphur, I am aware of the issue with regards to the reduction in atmospheric deposition and therefore the requirement for sulphates to be added through "fertilisers" and the mineralization of organic sulphur. In most typical agricultural soils (i.e. neutral soils) the sulphate behaves like nitrate, i.e. it is not bound and is easily leached.***
>
> ***RB209 (much as with the recommendations for nitrogen) provides guidance on the optimum sulphur addition to meet a particular crops need. Application rates above those recommended will present a risk of the excess leaching from the soil. If this excess sulphur enter surface waters it may affect the water's pH and be reduced to potentially toxic sulphides by the same anaerobic bacteria that will reduce nitrates to ammonia. Because the potential for excess sulphur to leach from a soil is similar to that for nitrogen the current advice provided on avoiding nitrate leaching is likely to be equally applicable, e.g. minimise leaching by following recommended rates and timings for fertilisers (see the Defra Code of Good Agricultural Practice for the Protection of Water).***
>
> ***I have calculated that you are applying 557 kg/ha of sulphur trioxide (which is what RB209 quotes) when spreading at 26 tonnes per hectare. The level recommended for silage is 25-40kg/ha when sulphur deficiency is noted prior to each cut."***

4Recycling's technical specialists have been asked to provide a detailed technical evaluation of the actual facts and chemistry of the interactions which occur when Ahlstrom black liquor is spread onto agricultural land.

2. INSTRUCTIONS

In response to the queries posed above by the Environment Agency, this report provides an analysis of the validity of the EA claims and provides researched technical details showing:

- The actual risk of leaching and water pollution and a review of literature to back up these facts.
- Data relating to the "polluting" potential of surface applied sulphate and sulphide, including the chemical reactions which compounds of this type undergo when mixed with organic and mineral matter in soil.
- Rate of leaching of S compounds added to soil compared with nitrate, Na and K.
- Characterisation of the S compounds in the black liquor, from current analysis or new analysis to show the speciation of S compounds.
- Whether or not current application rates are indeed safe and sustainable.

3. LITERATURE SEARCH

A literature search with specific reference to the application of Alhstrom type liquors, "Kraft black liquor" and sodium lignosulphonates to agricultural land yielded few experimental papers or reports of direct relevance.

One reference by Canmig Xiao (PhD thesis, Washington State University 2005) was more concerned with the fate of sodium from these liquors when applied to land and was proposing the substitution of sodium hydroxide with potassium hydroxide. His thesis did not study or consider the fate of the sulphur component of the liquor.

Discussions with Soil Scientists, both within the university community and external consultancies, provided little information on the Ahlstrom type liquors, or the soil chemistry of sodium sulphonates, and only a small amount of information on sulphate leaching that could be verified by experimental data.

It was striking how little information could be obtained on S leaching in soil or any EU or UK policy initiatives to restrict the movement of any S compounds from land to surface or ground waters. No comparison or linkage with nitrate leaching was evident.

Consequently, the report has been based on existing data from various reports commissioned by Alhstrom, analytical data from operational activities or appraised from current literature.

4. ANALYSIS OF THE AHLSTROM BLACK LIQUOR

Below is a summary of the most recent chemical analysis of the black liquor over the past 3 years.

		23.07.07	25.07.06	23.11.05	Mean
Dry matter	%	9.41	8.89	10.6	**9.63**
pH		8.6	8.94	7.93	**8.49**
Conductivity (1:6 ratio)	µS/cm	7720	6550	7480	**7250**
Total Nitrogen	% w/w	0.016	0.03	0.035	**0.027**
Nitrate Nitrogen	mg/kg	<0.1	<0.1		**0.00**
Ammonium Nitrogen	mg/kg	<0.1	13.4		**6.70**
Total					
Phosphorus (P)	mg/kg	42.4	8.33	15.1	**21.9**
Potassium (K)	mg/kg	2298	3165	2315	**2593**
Magnesium (Mg)	mg/kg	0.102	7.51	<0.01	**2.54**
Sulphur (S)	mg/kg	8573	3393	7738	**6568**
Sodium (Na)	mg/kg	16578		16411	**16495**
Calcium (Ca)	mg/kg	4.49	7.94		**6.22**
Water soluble					
Phosphorus (P)	mg/kg	40.6	6.8		**23.7**
Potassium (K)	mg/kg	2179	3065		**2622**
Magnesium (Mg)	mg/kg	0.8	6.9		**3.85**
Sulphur (S)	mg/kg	8426	3303		**5865**
Calcium	mg/kg	4.32	4.57		**4.45**
Total					
Copper	mg/kg	0.077	0.352	0.683	**0.37**
Zinc	mg/kg	0.016	0.759	7.51	**2.76**
Lead (Pb)	mg/kg	<0.01	0.027	0.207	**0.08**
Cadmium (Cd)	mg/kg	<0.01	<0.01	<0.01	**0.00**
Mercury (Hg)	mg/kg	<0.05	<0.05	<0.05	**0.00**
Nickel (Ni)	mg/kg	0.017	0.16	0.34	**0.17**
Chromium (Cr)	mg/kg	0.132	0.131	0.056	**0.11**
Lime Equivalent as CaO	% w/w	0.7	0.5		**0.6**

The analysis of the liquor shows it to contain significant quantities of potassium, sulphur, and sodium. The analysis also shows the liquor to be relatively consistent for dry matter, pH, electrical conductivity, sodium and calcium. The sulphur and sodium are derived from the extraction reagents, with the remaining nutrients derived from the dissolved plant matter.

The mean water soluble concentrations are higher than the mean total concentrations for some of the elements. This is due to the few sample numbers analysed and the variability of extraction techniques within the analytical methods.

Approximately 90% of the sulphur and calcium are soluble in water. However, this does not necessarily mean that these elements will be immediately available for plant uptake or leaching due to the fact that they are closely bound to the lignin.

The potentially toxic elements are all very low and will have an insignificant impact on the environment and/or plant uptake.

5. RATES OF APPLICATION AND FERTILISER VALUE

The fertiliser value has been calculated based on the mean values above and at an application rate of:

Application rate 30.0 t/ha

			Nutrient value	Amount applied
TOTALS	**result**	**units**	**(kg/tonne)**	**(kg/ha)**
Nitrogen (N)	0.27	g/kg	0.3	8
Ammonium-N	6.7	mg/kg	0.01	0
Phosphorus (P)	21.9	mg/kg	0.02	1
Phosphate (P2O5)			0.05	1
Potassium (K)	2593	mg/kg	2.59	78
Potash (K2O)			3.11	93
Magnesium (Mg)	2.54	mg/kg	0.00	0
Magnesium (MgO)			0.00	0
Sulphur (S)	6568	mg/kg	6.6	197
Sulphur (SO_3)			16.4	493
Sodium (Na)	16495	mg/kg	16.5	495
WATER SOLUBLE				
Phosphorus (P)	23.7	mg/kg	0.02	1
Phosphate (P2O5)			0.05	2
Potassium (K)	2622	mg/kg	2.62	79
Potash (K2O)			3.15	94
Magnesium (Mg)	3.85	mg/kg	0.00	0
Magnesium (MgO)			0.01	0
Sulphur (S)	5865	mg/kg	5.9	176
Sulphur (SO_3)			14.7	440

The major constituents of the liquor are sodium, sulphur and potassium. The amount of the nutrient applied from an application of 30 m^3/ ha is 93 kg/ha of potash, 197 kg/ha of S (493 kg/ha SO_3) and 495 kg/ha of sodium.

5.1 Potash

At this rate of application the liquor provides sufficient **potash** to meet most crop demands. Potash fulfils many vital functions in a wide variety of processes in plants, animals and man. It is typically taken-in in greater quantities than required and surpluses are naturally excreted. This process occurs in animals & humans via the kidneys and urine and in plants by the return of potash in senescent tissue at the end of each season - leaves from trees, cereal stubble and roots, etc. Potash is, therefore, naturally recycled widely and in large quantities. Soil reserves are an essential requirement for adequate nutrient supply of potash to plants which commonly contain more potassium than any other nutrient including nitrogen.

5.2 Sulphur

The amount of **sulphur** supplied is greater than crop demand, however, not all of the nutrients will be available for uptake as it is tightly bound to the lignin. This aspect will be discussed later in this report under "plant uptake". Sulphur is an important plant nutrient and needed by plants in similar quantities to phosphorus. Historically, the crop's requirement for sulphur has been met from atmospheric deposition and fertilisers that have contained sulphur as a by-product. However, sulphur deposition from the atmosphere has fallen rapidly in recent years and deposition in 1999 was about 15% of that in 1980. Sulphur deposition will continue to fall in the future.

5.3 Sodium

The amount of **sodium** applied is slightly more than that applied as agricultural salt to sugar beet crops e.g. 375 kg/ha (200 kg/ha Na_2O). The application will have no adverse effect on soil structure even on soils of low structural stability (RB209 Section 4, Pg 96). In addition, sodium is an essential element for grass herbage growth. Sodium fertilisers will not normally give extra grass yield but they will increase the Na content of grass which will improve the palatability of herbage and can reduce the chance of grass staggers. Sodium is also associated with a greater % of live herbage, higher D values and sugar content of grass. Research from Bangor University indicates that these effects increase milk output and % butterfat and may also have a small benefit on somatic cell count. Grass palatability and milk output increase at herbage sodium levels up to 0.5% in the dry matter.

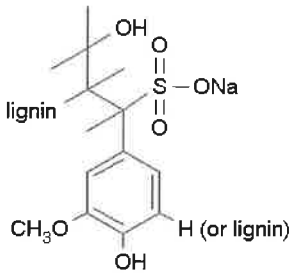
5.4 Potentially Toxic Elements

			Concentration	Amount applied	
TOTALS	result	units	(g/tonne)	(kg/ha)	Limit (kg/ha/yr)
Zinc	2.76	mg/kg	2.76	0.08	15.00
Copper	0.37	mg/kg	0.37	0.01	7.50
Nickel	0.17	mg/kg	0.17	0.01	3.00
Lead	0.08	mg/kg	0.08	0.00	15.00
Cadmium	0.00	mg/kg	0.00	0.00	0.15
Chromium	0.11	mg/kg	0.11	0.00	15.00
Mercury	0.00	mg/kg	0.00	0.00	0.10

The amounts of potentially toxic elements applied are insignificant to the amounts permitted under the "Sludge Use in Agriculture Regulations" (1989).

6. FORMS OF SULPHUR PRESENT IN THE BLACK LIQUOR

It is wrong to assume that because the analysis shows that the majority of sulphur is present in a water soluble form, that it must be present as sulphate or possibly sulphite. The extraction process uses sodium hydroxide and sodium sulphite to digest the plant material with the eventual formation of the complex molecule lignosulphonate. These are stable compounds and have been used as soil conditioners as they promote soil aggregation. The majority of the lignosulphonate will exist in the sodium form due to the amount of sodium sulphite added during the extraction process, but other base metals e.g. potassium and calcium derived from the plant material will also be present. The chemical structure of sodium lignosulphonate is shown below.



Lignosulphonates are stable molecules, with a molecular weight between 10,000-100,000, depending on their degree of the polymerization.

Lignosulphonates are also soluble in water, which is surprising considering their molecular weight. The C-S covalent bond and the S=O bonds will be broken by microbiological activity and not as a result of chemical reaction.

The Environment Agency appears to be concerned about sulphates leaching into surface or ground water resulting in the production of "potentially toxic" sulphides from the application of the Ahlstrom liquor. The release of sulphides from sulphates is a highly specialised process. It is carried out by specific sulphate reducing micro-organisms (Desulphovibrio bacteria) as a result of anaerobic respiration, and will not occur in normal aerated agricultural soils. It can not be reduced by the same micro-organisms as those which reduce nitrate to ammonia as has been implied by the Environment Agency.

Conditions in soil or water need to be intensely anaerobic in order for sulphate reduction to occur. The following table shows the sequence of oxidation-reduction potentials for inorganic reductions that poise a soil as it becomes more anaerobic.

System	Redox potential at 25 °C (mV)	
	pH 5	pH 7
$O_2 + 4H^+ + 4e^- = 2H_2O$	930	820
$NO_3^- + 2H^+ + 2e^- = NO_2 + H_2O$	530	420
$MnO_2 + 4H^+ + 2e^- = Mn^{2+} + 2H_2O$	640	410
$Fe(OH)_3 + 3H^+ + e^- = Fe^{2+} + 3H_2O$	170	-180
$SO_4 2- + 10H^+ + 8e^- = H_2S + 4H_2O$	-70	-220

In normal aerated agricultural soils the redox potential is poised above +400 mV, depending on soil conditions. Soil respiration systems will be based on oxygen, nitrate, manganese and iron depending on the soil conditions. However, for sulphate reduction to occur, the soil must be extremely waterlogged (bog conditions) and sulphate reducing micro organisms to be present. Consequently, sulphate reducing conditions are highly unlikely to occur under normal soil conditions for crop production.

7. SULPHUR IN SOILS

Sulphur occurs in the soil in both inorganic and organic forms, with the organic bound S comprising of over 90% of the sulphur. The majority of the inorganic sulphur will be present as sulphates of varying solubilities.

Soil analysis form fields where the Ahlstrom black liquor is to be applied show total sulphur contents ranging from 0.02% to 0.08 % S. This equates to a total sulphur content ranging from 500 to 2000 kg/ha S, assuming that a hectare of soil in the top 20 cm weighs approximately 2,500 tonnes.

8. INFILTRATION TRIALS

Soil infiltration tests were carried out by Dr R Davies, Soil Environment Services. The infiltration rate was assessed with a double ring infiltrometer on two soil textures using both water and Ahlstrom 410 liquor. The Philips equation was used to calculate infiltration after 1 hour and the average for water was 85 mm/hr and for Ahlstrom liquor 56 mm/hr. This was carried out during relatively dry conditions and therefore could be expected to be half this rate during wetter conditions.

Based on these infiltration data, an application rate of 29.76 tonnes per ha will, therefore, result in percolation of the black liquor to no more than 2.9 mm depth if spread uniformly on the soil when soil conditions were suitable (not during rain or when the soil is at field capacity). If the liquor is applied at moisture contents less than field capacity, the liquor will infiltrate at the above rates but will not pass through the profile due to the relatively small quantities applied and will add very little to the soil moisture content. The soil mass available to absorb the liquor would be expected to retain all of the nutrients and liquor constituents.

This means that the surface soil layer enriched with the black liquor will need to be flushed with a very large quantity of excess winter rainfall (annual rainfall minus evapo-transpiration) to push the material through the soil profile like a piston, assuming the constituents are freely mobile.

9. PLANT GROWTH TRIALS (BIOASSAY)

Plant growth trials utilising the Ahlstrom liquor carried out in 2000 has shown a number of interesting results both in terms of nutrient uptake and the effect on the soil. The black liquor used in the bioassay contained between 3-6 times the quantity of sodium and sulphur respectively as is now contained within the black liquor recycled to land (mean data shown in this report). Although not directly comparable, the data can be used to demonstrate nutrient uptake and residual soil nutrient effects of the application of the black liquor to soil.

9.1 Nutrient uptake

Table 1 shows the effect on nutrient uptake in grass as a result of increasing the rate of application of the Ahlstrom liquor from 0 to 50 m^3/ha. The largest effect was the reduction in the potassium and the increase in sodium concentrations. The Ahlstrom liquor supplied the equivalent of 354 kg/ha of sodium at the 6 m^3/ha application of liquor. Sodium uptake was increased from 0.1 % to 0.31 % at the 6 m^3 rate and up to 1.07% at the 50 m^3 rate. The increase in sodium uptake suppressed the uptake of the other cations. This effect was not observed in the uptake of sulphur, despite an application of 222 kg/ha of sulphur (555 kg/ha SO_3) at the 6 m^3 application rate. The sulphur content only increased from 0.24% to 0.26% at the 25 m^3/ha treatment despite the application of the equivalent of 925 kg/ha of sulphur (2,300 kg/ha SO_3). This demonstrates that the majority of the sulphur can not be present in a plant available form, e.g. sulphate, and is therefore, not likely to be leachable.

Table 1 - Nutrient content of grass (%).

Treatment (m^3/ha)	DM (%)	N (%)	P (%)	K (%)	Mg (%)	Na (%)	S (%)	Cu (mg/kg)
0	14.4	2.90	0.38	4.28	0.14	0.10	0.24	6.87
6	14.8	2.63	0.37	3.96	0.12	0.31	0.22	6.43
12	15.9	2.70	0.34	3.48	0.12	0.54	0.22	6.21
25	16.3	2.48	0.30	3.06	0.11	0.73	0.26	5.65
50	16.9	2.45	0.33	2.56	0.09	1.07	0.27	6.32
SE	0.512	0.134	0.014	0.104	0.007	0.025	0.009	0.350
Sig	5%	NS	5%	0.1%	1%	0.1%	5%	NS

Similar results were observed in oilseed rape (Table 2) and the results presented below. There was a similar reduction in the potassium content, and increase in the sodium content. The differences in the nitrogen, phosphorus and sulphur contents as a result of applying the Ahlstrom liquor were not significant.

Table 2 - Nutrient content of oilseed rape (%)

Treatment (m^3/ha)	DM (%)	N (%)	P (%)	K (%)	Mg (%)	Na (%)	S (%)
0	11.2	2.27	0.39	4.37	0.26	0.08	0.87
6	11.2	2.25	0.38	4.15	0.24	0.34	0.85
12	12.1	2.05	0.36	3.57	0.23	0.47	0.79
25	11.7	2.11	0.36	3.47	0.21	0.75	0.79
50	11.7	2.19	0.40	3.09	0.20	1.12	0.91
SE	0.416	0.061	0.013	0.166	0.008	0.049	0.031
Sig	NS	NS	NS	0.1%	1%	0.1%	NS

The normal application rate of **30 m^3/ha**, is based on the mean fertiliser value of the Ahlstrom liquor in this report and it will apply the equivalent amount of sodium and sulphur as the 6m^3/ha treatments used in the plant growth trials.

9.2 Soil analysis

At the end of the plant growth test carried out in 2000, the soils were analysed and the results presented in Table 3.

Table 3 - Soil analysis - Grass

Treatment (m^3/ha)	pH	Extractable (mg/l)			Ext Na mg/l	Total S mg/kg	Ext SO_4-S mg/kg	Cond µS/cm 20°C	Ext Cu (mg/l)
		P	K	Mg					
0	6.9	36	243	107	19	333	31	2063	5.4
6	6.9	37	224	113	29	349	22	2043	4.9
12	7.0	45	245	136	56	380	57	2100	5.5
25	7.0	40	210	126	133	422	60	2100	5.1
50	7.1	36	234	109	164	446	51	2185	4.9
SE	**0.056**	**3.85**	**27.88**	**4.914**	**31.221**	**24.38**	**17.507**	**31.992**	**0.171**
Sig	**5%**	**NS**	**NS**	**1%**	**5%**	**5%**	**NS**	**NS**	**NS**

The addition of the Ahlstrom black liquor had no significant effect on the available phosphorus, potassium and magnesium content. There was a small significant increase in soil pH which would offset concerns of potential soil acidification resulting from the application of the Ahlstrom liquor.

There was a significant increase in the sodium content but this increase was small at the $6m^3$ /ha rate and would have little impact on the soil. This rate of application would apply the same sodium loading as a 30 m^3/ha application of the current black liquor based on the mean value in this report.

There was a significant increase in the total sulphur content but this increase was not significant at the $6m^3$/ha application rate. There was no significant increase in the plant available sulphate (SO_4-S) even at the $50m^3$/ha rate which supplied 1,650 kg of water soluble–S (4,000 kg SO_3-S). These data further confirms that although the sulphur is in water soluble form, it is not being measured by standard soil tests to identify sulphur that is readily available for plant uptake or leaching.

10. LEACHING OF SULPHATE

The leaching of sulphate was of primary concern by the Environment Agency. These concerns are unproven as the risk of pollution resulting from sulphate leaching is relatively small. This is because the sulphur is present in the form of lignosulphonates which will be organically bound to the soil. The lignosulphonates although soluble in water, are not extracted by standard soil analysis methods that measure the forms of sulphur that are readily leached or available for plant uptake.

The following analysis is based on **all the sulphur being soluble and available for leaching** and was modelled in order to satisfy the Environment Agency that sulphate leaching is unlikely to occur. The amount of S leached is calculated from the current application rate of 30 m^3/ha using nitrate-nitrogen leaching as baseline (assuming S leaching losses are equivalent to nitrate). The amount of nitrate-nitrogen can be calculated using the ADAS Manner programme for a range of soil types and the 3 excess winter rainfall classes described in MAFF bulletin 209. The programme has been set so that all the nitrogen is available for leaching, and that the material is applied to the surface and incorporated within 2 hours of application. The programme calculates that only 6 kg/ha of nitrate-nitrogen is lost through volatilisation, with the remainder available for leaching.

The following excess winter rainfall scenarios have been used to represent the 3 rainfall classes:

Rainfall Class	Excess winter rainfall range	Excess rainfall used in calculation
Low (500-600 mm)	50-150 mm	100 mm
Moderate (600-700 mm)	150-250 mm	200 mm
High (700 + mm)	250 + mm	300 mm

The following table calculates the amount of nitrate-nitrogen leached from an application of 176 kg/ha of available N. This is the same rate of application of water soluble sulphate–S applied in the Ahlstrom liquor applied at 30 m^3/ha. The soil textures are the same for both the topsoil and subsoil.

Amount of NO_3-N leached from an application of 176 kg/ha available N

Excess rainfall	Sandy loam	Silt loam	Clay loam	Clay
100 mm	0	0	0	0
200 mm	71	5	13	31
300 mm	162	76	89	118

The leaching of sulphate–sulphur is generally accepted as approximately 66% that of nitrate-nitrogen. The amount of sulphate-sulphur that is available for leaching can be calculated and presented in the following table. The data has not taken into account:

- any sulphur taken up by the crop which would be in the order of 24 kg/ha S (60 kg/ha SO_3), based on a 2 cut silage system removing 12 kg/ha S (30 kg/ha SO_3 per cut), or
- any sulphur immobilised by the soil.

Amount of SO_4-S (mg/l) leached from an application of 176 kg/ha water soluble S

Excess rainfall	Sandy loam	Silt loam	Clay loam	Clay
100 mm	0	0	0	0
200 mm	47	3.3	8.0	20.4
300 mm	107	50	59	78

The data in the above table is for the worst case scenario where 100 % of the applied sulphur is available for leaching. The following table calculates the concentration of sulphate in the drainage water based on the amount of SO_4-S leached for the 4 different soil textures and three excess winter rainfall classes.

Amount of SO_4-S (mg/l) in drainage water from an application of 176 kg/ha water soluble S

Excess rainfall	Sandy loam	Silt loam	Clay loam	Clay
100 mm	0	0	0	0
200 mm	23.5	1.7	4.0	10.2
300 mm	35.7	16.7	19.7	26.0

The calculations above from MANNER show that small concentrations of SO_4-S **(worst case scenario 35.7 mg/l SO_4-S)** would be present in the drainage waters and would not pose a significant risk to the environment. The majority of soils used for spreading the black liquor will be clay loam or sandy clay loam in texture with leaching rates similar to the clay loam texture e.g. 19.7 mg/l SO_4-S. To put this into context, the World Health Organisation, US Environmental Protection Agency and the The Water Supply (Water Quality) Regulations 2000 all show a figure of 250 mg/l sulphate as a guide upper limit for drinking water. The limit is not set not because this is a potentially harmful limit but because it could affect the taste of the water.

All of the analysis above has assumed that:

- S can leach at the same rate as nitrate which it can not.
- All of the S applied to land in the form of the black liquor is soluble and there is no resistance to leaching when there must be.
- The lignosulphate does not bind with the soils organic matter when it must.
- There is no crop uptake and there must be in practice.

The present environmental legislation does not include any specific limitations to sulphur application or its impact on the environment or provide policy advice or action programmes to control sulphur additions to surface or ground waters. The only indirect reference to sulphur application is stated in the RB 209 "Fertiliser Recommendations" which state that applications should be linked to crop requirement.

The environmental impact of spreading the liquor in a catchment would be very small for 2 reasons:

- firstly due to the huge dilution effect of the addition of the black liquor over a very large area of land
- secondly due to the remote possibility of spreading similar wastes containing a high sulphur content within a catchment.

11. CONCLUSIONS

11.1 A literature search with specific reference to the application of Alhstrom type liquors, "Kraft black liquor" and sodium lignosulphonates to agricultural land yielded few experimental papers or reports of direct relevance. Consequently, the report has been based on existing data from various reports commissioned by Alhstrom, or appraised from current literature.

11.2 The analysis of the liquor shows it to contain significant quantities of potassium, sulphur, and sodium. The total amount of the nutrients applied from an application of 30 m^3/ha is 93 kg/ha of potash, 197 kg/ha of S (493 kg/ha SO_3) and 495 kg/ha of sodium.

11.3 The majority of sulphur present is water soluble in the form of a complex molecule lignosulphonate. These are stable compounds and have been used as soil conditioners to promote soil aggregation.

11.4 The leaching of sulphate was of primary concern by the Environment Agency. These concerns are unproven as the risk of pollution resulting from sulphate leaching is relatively small. This is because the sulphur is present in the form of stable lignosulphonate molecules which will be organically bound to the soil.

11.5 The sulphate leaching was modelled in order to satisfy the Environment Agency's concerns. The model was based on worst case scenario in that all of the sulphur was in a soluble form and available for leaching. The calculations show that based on this precautionary analysis that only small concentrations of SO_4-S could be present in the drainage waters and would not pose a significant risk to the environment.

11.6 Based on the analysis of pollution risk from leaching of sulphur compounds in this report, the current application rate of up to **30 m^3/ha** will have little or no adverse impact on the soil and pose a negligible risk to the environment. The beneficial effects of the application of Ahlstrom black liquor on crop growth have been proven in earlier experimental work, from the provision of Professionally Qualified Advice and from operational experience.