Llanddulas Landfill Site

Annual Monitoring Review

February 2018 to January 2019 inclusive

Prepared by P. Birchall

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1.0 INTRODUCTION

1.1 Background

FCC Environment has, in accordance with Permit condition 4.2.1a, undertaken an annual review of site monitoring data for Llanddulas Landfill collected between the period 1st February 2018 and 31st January 2019. The site is managed under a PPC Permit Ref. BU0800 and Permit Variations CP3332LG and BG3734XX.

Monitoring data has been submitted previously to the Environment Agency, and data represented within the Tables and Appendices of this report focuses on any issues or exceedances highlighted throughout the review, as required, to illustrate trends and support discussion. This report concentrates on those aspects of the monitoring that have been given trigger limits / emission limits by Natural Resources Wales (NRW) and / or other indicators of landfill impact. It does not attempt to present all data collected throughout the review period, but instead assesses whether or not the landfill is having an environmental impact and whether monitoring results are as expected.

1.2 Site Location and Surrounding Land-use

The Llanddulas Landfill (centred at National Grid Reference: SH 904 775) is located to the immediate south-west of Llanddulas village, approximately 5 km to the east of Colwyn Bay (Drawing No. 1).

Llanddulas Landfill is located on an east/north-east sloping hillside with surface elevations falling from approximately 180mAOD, at the site's southern corner, to 120mAOD at the site's entrance tunnel beneath Pentregwyddel Road in the north. To the east of the quarry, the ground level falls steeply away to elevations of between 25 and 30mAOD, which are associated with the Afon Dulas Valley (sometimes referred to as the 'Dulas Gap').

In terms of surrounding land use, agricultural grassland and open pasture lie immediately adjacent to the site's western and southern boundaries, while development associated with Llanddulas village is present along the site's north-eastern boundary. Much of the eastern site boundary lies adjacent to limestone crags that form the upper slopes to the steep valley of the Afon Dulas. This area lies within the 'Llanddulas Limestone and Grwyth Castle Wood' Site of Special Scientific Interest (SSSI), which is of special interest for its limestone grassland, heath and woodland communities.

A worked-out quarry (the 'Lower Quarry') is located to the immediate north-west of the landfill site. This quarry is no longer operational and now holds a series of lagoons. Historically these lagoons were used to treat effluent generated by the on-site mineral processing plant. However, following the cessation of mineral extraction, their operational use has been limited to providing water for dust suppression activities.

1.3 Site History and Development

Quarry operations at Llanddulas have been on-going for over 100 years, with operations beginning within the Lower Quarry located to the immediate south of the old A55 Coast Road. Mineral extraction moved progressively southwards, with the area to the south of Pentregwyddel Road being developed subject to a number of planning approvals.

Phase 1 of the Llanddulas Landfill was developed by Colwyn Borough Council during 1985 and landfilling within Phase 1 was initially completed during 1994. However, further re-profiling occurred within Phase 1C during the latter part of 2001 in order to increase the height of the site

and to correspond to the appropriate restoration contours. These operations allowed the capping and restoration of previously unrestored areas of this phase.

During the reporting period the Central area of Phase 3A was operational, the North, Western, North Eastern area and the Southern half are now all capped.

1.4 Geology

The superficial deposits present within the vicinity of the landfill are located to the east and north-east of the site and comprise Boulder Clay. These materials are present within the base of the Afon Dulas valley as well as the western and eastern valley sides. It is anticipated that the greatest depth of this material is located within the Afon Dulas valley, although there is no direct evidence to confirm this. In addition to the Boulder Clay, River Terrace Deposits and Alluvium are also associated with the water course.

The solid geology comprises limestones deposited within the Carboniferous Limestone Series. More specifically, the site is located in the Dyserth Limestone Group. Below the Dyserth Limestone Group and outcropping several hundred metres to the south of the site are the Carboniferous Limestone Basement Beds, which comprise a variable sequence of limestones, sandstones and conglomerates. The local dip of the limestone beds is approximately 15 degrees towards the north-north-east.

There are four main faults located within the vicinity of the site, the details of which are as follows; the Llysfaen and Plas Farm Faults are orientated approximately east to west and traverse the quarry. Both faults dip towards the south at approximately 45 degrees and have around 40m of displacement to the south.

The Llysfaen fault is located to the immediate south of Phases 1 and 3 and north of Phase 2. The Plas Farm Fault effectively defines the southern extent of the currently consented landfill area. The Dulas Gap Fault is orientated north to south and is near vertical with a downthrow of approximately 75m to the east.

The geological map information for the area suggests that this fault truncates the eastern ends of the Llysfaen and Plas Farm Faults. It is probable that the Llysfaen Fault is downthrown by the Dulas Gap Fault. If this is the case, then the surface manifestation of the truncated Llysfaen Fault could be in the location of the Dulas Spring, owing to the dip of the Llysfaen Fault to the south and the 75m downthrow to the east of the Dulas Gap Fault.

The Tyn-y-Caeau Fault located to the east of the Dulas Gap Fault is near vertical and has a 120m throw to the west. It intersects the Dulas Gap Fault to the north of the quarry. In addition to the above, smaller unnamed faults are present to the south of Llanddulas Landfill within the southern end of the quarry. Two sets of vertical joints, parallel to the geological strike are also present.

1.5 Hydrogeology

The site is located within the Carboniferous Limestone Series, which is classified as a "principal aquifer" within the Groundwater protection policy, 2010, owing to the rock potentially possessing significant fracturing and extensive well-developed joint system and the potential for high bulk permeability. This classification is confirmed by the Groundwater Vulnerability Map1 for the area.

The Carboniferous Limestone aquifer is a hard rock where primary porosity is low (less than 1%) and flow through open cavities, such as fractures, fissures and joints, is dominant. The Carboniferous Limestone is mechanically strong, but can undergo solutional weathering (karstification) which, under some circumstances, can produce caves (conduits) through which groundwater can flow preferentially.

Even though preferential routes exist within the Carboniferous Limestone aquifer, an extremely large volume of aquifer will still consist of rock that possesses tight fractures where water flow is extremely slow (i.e. the diffuse zone). The diffuse zone of the Carboniferous Limestone aquifer is generally highly anisotropic, that is to say that hydraulic conductivities vary significantly with direction. Groundwater flow within a karstified Carboniferous Limestone aquifer usually occurs along bedding planes, which are laterally continuous within the rock.

1.6 Hydrology

The main watercourse within the vicinity of Llanddulas Landfill is the Afon Dulas, located approximately 200 to 400m to the east of the site. This watercourse flows in a northerly direction and discharges into the Irish Sea approximately 1.3km to the north-east of the site. The coastline lies approximately 600m and 300m to the north of Phase 1 and the Lower Quarry areas respectively. An unnamed tributary of the Afon Dulas, which flows in an easterly direction, is located over 1km to the south of the site.

Indicative maps, presented on the Environment Agency's website, suggest that the floodplain associated with the Afon Dulas is extremely limited. Llanddulas landfill does not lie in any indicative flood plain.

2.0 LANDFILL GAS REVIEW

Routine monitoring for off-site landfill gas was undertaken on a fortnightly basis within 33 perimeter monitoring boreholes and monthly in a further 42 in accordance with the requirements of Table S4.5 of the Site Permit issued in June 2016. Following the new Permit issue, monitoring of perimeter boreholes was reduced in the most recent variation to fortnightly for the boreholes in the higher risk (of migration) area of site on the Eastern boundary and monthly for all perimeter boreholes.

Methane, Carbon Dioxide, Oxygen, relative pressure and atmospheric pressure are all recorded.

The locations of monitoring points are shown on the site monitoring plan, Drawing No. 2.

The trigger levels for landfill gas concentrations are those submitted and agreed with NRW in accordance with improvement condition S1.3.13, agreed with the then EA Wales in November 2012 (CAR form RDR/121105). The trigger limit for methane is 1% (action limit of 0.5%), with the exception being 2.5% in borehole BH40 which has an action limit of 1.5%. Specific actions to be taken if the limits are breached are detailed in the latest version of the site Landfill Gas Management Plan. Borehole specific CO2 action limits were also agreed.

2.1 Landfill Gas Data Summary

There were no breaches of the current methane trigger limit of 1.0% (v/v) throughout the reporting period. The highest methane concentrations recorded were 0.2% (v/v) in boreholes BH40, BH41 & BH42 all on the 19th December 2018, which is most likely a result of Gas Analyser drift, which has a CH4 uncertainty of -/+ 0.5% in the lowest gas volume range.

Since November 2012 (following the agreement of CO2 Action Limits, as part of the IC13 submission), Carbon Dioxide has no longer been used as a landfill gas migration indicator in the absence of methane.

To summarise, there are no trends of elevated Methane within the perimeter boreholes that would indicate ongoing lateral migration of landfill gas beyond the site perimeter. Elevated readings of Carbon Dioxide are thought to be present because of the localised geology.

2.2 Landfill Gas Management

Landfill gas control currently consists of 2 X Jenbacher engines located in the LFG utilisation plant, comprising of 2 x 1003kW engines. In addition there is 1 X 2000m3 high temperature flare and 1 X 1000m3 high temperature flare which can provide sufficient gas control should the engines suffer any downtime.

The landfill gas control system was monitored in accordance with Tables S4.1, S4.2 and S4.7 of the site Permit, with a total of 3,393 readings taken throughout the review period. The annual trace gas analysis and engine emissions data are appended to the end of this report. After a review of the data, the following observations can be made.

- The average measured emission concentrations from the combined stack met the standard for NOx, CO and TVOC as per Table S4.2 of the site permit on Engine 1 (A2) and Engine 2 (A3).

- Compared with the results from last year, some components of trace gas have increased, others have decreased. 1,1 Dichloroethane, 1,2 Dichloroethane, Dichloromethane, Styrene, Arsenic,

Hydrogen Sulphide and Acetaldehyde have all increased during this review period compared with the previous review period.

- 1 Pentene, 1,2 Dichloroethylene, 1,4 Epoxy 1,3-Butadiene, Benzene, Carbon Disulphide, Dimethyl Disulphide, Dimethyl Sulphide, Ethyl Butyrate, Toluene, Vinyl Chloride Monomer and Formaldehyde have all decreased during this review period compared with the previous review period.

- The flares ran significantly less than 10% of the time during the review period, and therefore emissions' testing was not required.

- Average methane concentrations for the gas extraction wells during the review period were 38.67% (v/v), and average carbon dioxide concentrations were 27.93% (v/v). At the gas plant inlet, methane concentrations averaged 43.52% (v/v) and carbon dioxide averaged 31.86% (v/v).

- Carbon monoxide concentrations averaged 3.46ppm for the duration of the review period at the gas extraction wells, and 3.68ppm at the gas plant inlet.

- Oxygen readings at the gas extraction wells averaged 2.90% (v/v) throughout the review period, and recorded an average of 1.68% (v/v) at the gas plant inlet.

- Suctions within the field averaged -29.79mbar for the duration of the review period, and at the gas utilisation plant averaged -83.80mbar.

- The average flow recorded at the gas utilisation plant during 2018 was 813m3/hr and produced an average of approximately 1309kW of exportable energy per month.

- No CO readings taken at any gas wells breached the 100ppm limit. The highest reading recorded was 53ppm in gas well WD281 in January 2019.

The effectiveness of the gas management system is tested by monitoring gas compositions at the gas collection and extraction wells. Monitoring of the gas extraction system is carried out in accordance with the requirements of Tables S4.2 and S4.7 of the site Permit. Table S4.7 specifies that where oxygen levels exceed 5%(v/v), or where the addition of Carbon Dioxide and Methane percentages is less than 80%, an assessment of air ingress shall be undertaken.

There were a total of 3,393 readings obtained during the review period and of these, there were 1817 results which showed a total percentage of Carbon Dioxide and Methane of less than 80% (v/v) which was 54% of the readings.

A total of 542 results showed O2 in excess of 5% which was 16% of the total readings for 2018. Assessments of these wells showed that the majority of readings led to the valves at these points being closed or significantly reduced, to prevent any potential oxygen ingress, yet maintaining a degree of gas control. Investigations are actioned when the control limits specified within Table S4.7 of the Site Permit are exceeded and corresponding remedial actions promptly instigated by our gas contractors.

To summarise, the current landfill gas infrastructure is deemed to be adequate for the control of emissions on site, although with decreasing waste inputs with reducing biodegradable content gas volumes are seen to be declining over previous review periods.

GROUNDWATER REVIEW

3.1 Groundwater Levels

Table S4.10 of the site permit, requires that groundwater levels are recorded on a quarterly basis within the up, down and cross gradient groundwater monitoring points.

Summaries of the available groundwater level data are presented below.

Borehole	No. of readings	Minimum	Maximum	Average	Range
GWBH01	4	93.00	98.67	95.69	5.67
GWBH02	5	66.69	68.92	68.04	2.23
GWBH04	5	9.63	20.44	16.37	10.81
GWBH06R	5	98.38	99.12	98.74	0.74
GWBH07	4	3.48	8.16	5.23	4.68
GWBH22	3	8.91	13.57	11.78	4.66
GWBH23	4	Dry	Dry	Dry	Dry
GWBH24	4	3.41	4.09	3.83	0.68
GWBH25	3	41.38	43.55	42.70	2.17
GWBH26B	4	48.51	49.18	48.79	0.67
GWBH27B	4	15.64	16.88	16.36	1.24
GWBH28	4	32.10	33.41	32.94	1.31
GWBH32	6	97.21	128.38	103.34	31.17
GWBH33	6	105.52	115.80	109.85	10.28
GWBH34	5	128.52	130.96	129.84	2.44
GWBH35	4	126.32	128.00	127.39	1.68
GWBH36	6	82.36	106.98	94.75	24.62

The groundwater level beneath the site varied between 3.41mAOD in borehole GWBH24 (downstream of groundwater flow across site) located in Llanddulas village to the North-East of site and 130.96mAOD in GWBH34 on the Southern boundary. GWBH23 was reported as dry throughout the review period.

The elevations of groundwater have increased substantially over the previous review period.

The wide variation in groundwater levels is in part a function of the wide variation in topography across the site ranging between 180mAOD to the south and 30mAOD in the north. It is also possible that proximity to the sea could give rise to tidal fluctuations within the aquifer, especially in the more northerly boreholes. Wide groundwater fluctuations are typical of karstic aquifers and their response to recharge events.

The range in AOD groundwater levels within the individual boreholes varied from just 0.67m in GWBH26B to a maximum of 31.17m in GWBH32. It is common to observe a wide variation because the nature of recharge event response varies depending on the degree of fissuring or solution cavity exposed to the screened section of the monitoring well.

3.2 Groundwater Quality

Groundwater samples are scheduled to be taken in accordance with the requirements of Table S4.4 and S4.10 of the Site Permit.

Table S4.4 of the site permit variation contains borehole specific trigger levels for groundwater quality which are detailed below.

Trigger levels for emissions into groundwater			
Boreholes GWBH4, GWBH7, GWBH23, GWBH25, GWBH34, GWBH35 & GWBH36			
Parameter	**Limit**	**Parameter**	**Limit**
Ammoniacal-N	1mg/l	Potassium	12mg/l
Chloride	250mg/l	Phenols	0.5ug/l
Mercury	0.01ug/l	Tributyl Tin	0.001ug/l
Mecoprop	0.04ug/l	Trifuralin	0.01ug/l

The following observations can be made in relation to groundwater quality:

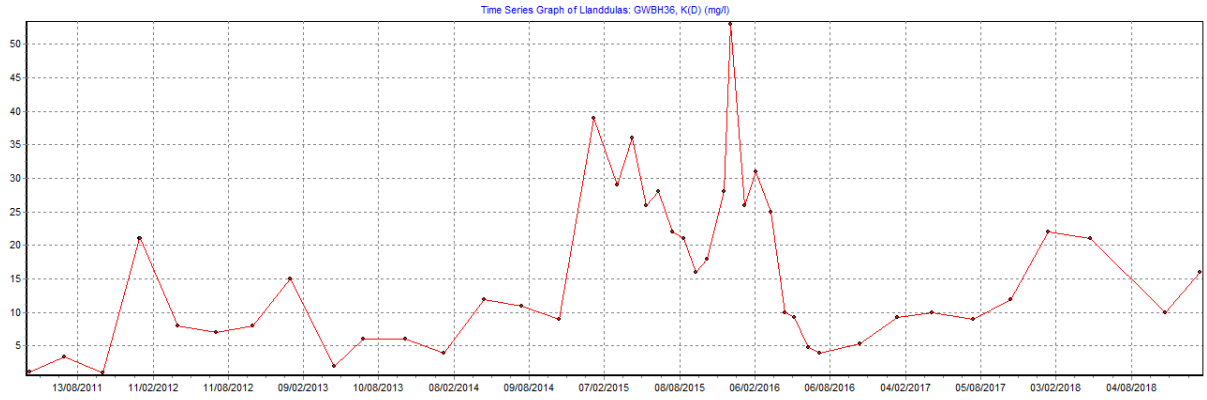
There were no breaches of the site permit specific trigger limit for Chloride, Mecoprop, Tributyl Tin or Trifuralin throughout the review period. Chloride concentrations ranged from 12mg/l in borehole GWBH02 to 153mg/l in borehole GWBH24, recording an average across all boreholes of 48.86mg/l.

Ammoniacal Nitrogen concentrations exceeded the compliance limit on 2 occasions with a result of 3.6 mg/l in GWBH04 during July 2018 monitoring, and 1.3mg/l during July in GWBH22. There were no further breaches in these monitoring locations throughout the remainder of the review period. All other boreholes were within compliance limits.

Two Mercury exceedances were recorded during the review period in borehole GWBH04 during July and October monitoring recording a result of 0.03ug/l and 0.02ug/l against a trigger limit of 0.01ug/l. All remaining results were within compliance limits.

There have been historic breaches of the potassium limit in borehole GWBH36, and during the review period a concentration of 21mg/l was observed in April, and in the following quarter a concentration of 16mg/l was recorded. All other determinands and key pollutant indicators have not shown elevated levels or upward trends. The average ammoniacal nitrogen concentration during the review period was recorded as 0.02mg/l with a maximum concentration of 0.03mg/l recorded. Chloride averaged 57.66mg/l with a maximum concentration of 70mg/l observed. This borehole is located upstream of the Dulas Valley Spring which has shown no deterioration in water quality during the last 36 months.

A review of the previous 10 years results would indicate historical elevated spikes predominantly during the winter months as illustrated graphically below.



During the review period, there was a single phenol exceedance observed in borehole GWBH27B in July 2018, recording a concentration of 1.4ug/l. All results obtained in this boreholes and all others during the review period were recorded as below the limit of detection.

To summarise, groundwater quality is generally considered to be consistent with historic review periods. There are no trends evident within the data sets that would indicate a potential failure in the site containment system.

There were occasional elevated results observed but none that would indicate a potential risk to the surrounding environment. An assessment has also been made against the most recent HRA and background results tend to be consistent with the Environmental assessment limits. An updated HRA has been compiled and is currently being reviewed.

4.0 LEACHATE REVIEW

Leachate levels are recorded on a monthly basis in accordance with Table S4.1 of the most recent Site Permit Variation (June 2016). Leachate samples are collected on a quarterly basis as agreed in writing (April 2013) with Natural Resources Wales.

Locations of the monitoring points can be found on Drawing 2, attached with this report.

The leachate samples are analysed for a range of determinands as specified in Table S4.8 of the Site Permit.

4.1 Leachate Levels

Leachate monitoring within restored and active phases currently occurs at 7 leachate extraction and 7 leachate monitoring points in accordance with the requirements of Table S4.1 of the site Permit. During the review period, all chambers recorded levels below the 2m trigger limit attaining a 100% compliance result. Each leachate chamber is checked weekly by site staff to ensure correct pumping operation and all leachate generated was treated via the on-site LTP.

4.2 Leachate Quality

The leachate quality was scheduled to be monitored in 7 Leachate Collection Points (across phases 1, 2, 3 and 3A) and compared to assessment limits set in the HRA (summarised below).

Parameter	Limit
Ammoniacal-N	3500mg/l
Chloride	3900mg/l
Lead	120mg/l

It should be noted that leachate composition will vary with the age and moisture content of the waste.

After a review of the leachate quality data, the following comments can be made:

- Ammoniacal-N concentrations were recorded below assessment level for the duration of the review period, with the highest concentration of 2640mg/l detected in LCP3A, the newest chamber on site. A minimum concentration of 403mg/l recorded in chamber LCP1AR represents the oldest chamber on site. An average concentration of 1541mg/l was recorded throughout the review period.

- Chloride concentrations were consistently below the assessment level throughout the monitoring period, with a maximum concentration of 3500mg/l recorded in chamber LCP2Br2, a minimum concentration of 1050mg/l in chamber LCP1AR, and an average concentration of 2547mg/l recorded throughout the review period.

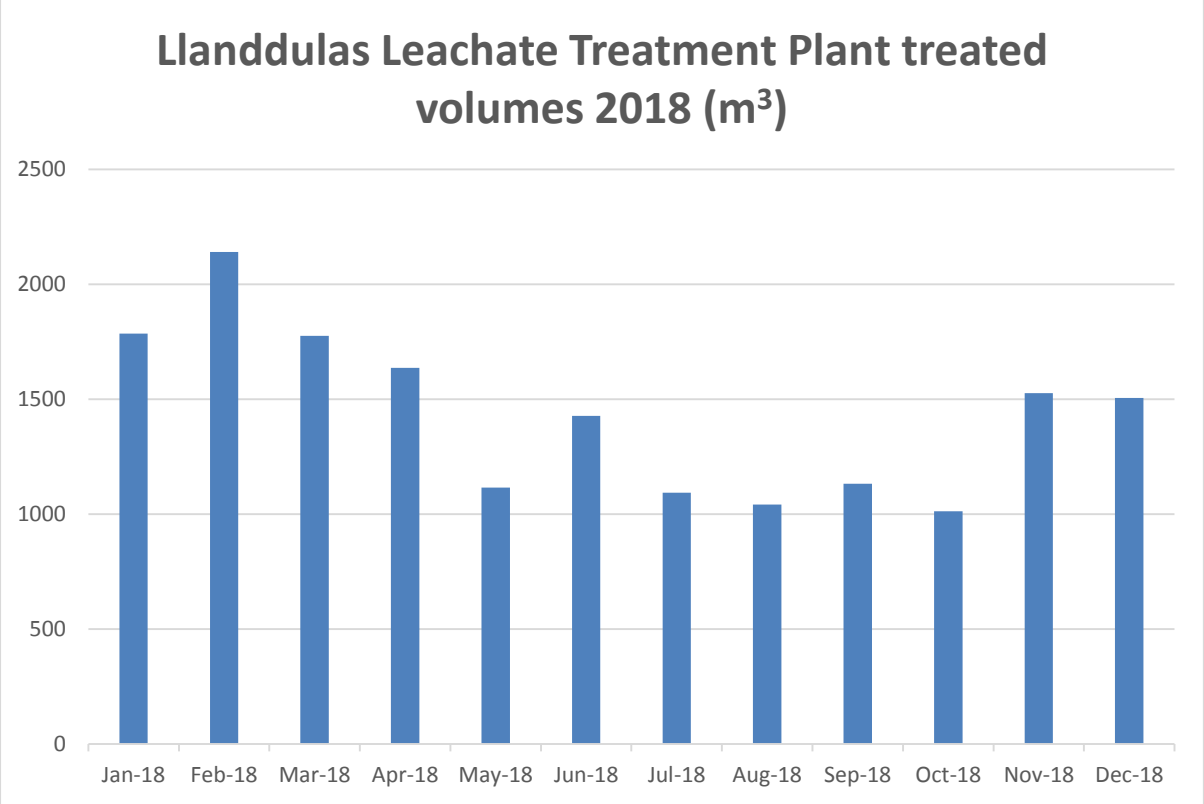
- Lead was only recorded once throughout the review period as 0.002mg/l in chamber LCP1AR, with all other results being below the limit of detection.

- The leachate quality remains as modelled and appears to be typical of a landfill site that received a variety of waste types.

4.3 Leachate Management

A total of 38,055 m3 of leachate was treated at the on-site treatment plant during 2018, approximately 1,600m3 less than in 2017. This total includes imported leachate from either other FCC sites or from landfill sites on Anglesey. Leachate is pumped from 7 collection chambers, 6 monitoring points and in addition a series of pumped 'pots' which range in depth from 10m to 15m. Leachate is also pumped to the LTP from a number of gas wells. Priority is always given to the treatment of on-site leachate when the plant is at full capacity of 150m3/day.

See graph below of monthly leachate treated volumes *excluding* imported leachate during 2018.



5.0 SURFACE WATER REVIEW

Surface water is scheduled to be sampled in accordance with Table S4.3 and S4.9 of the Site Permit.

There were no emissions through the consented discharge point W1 for the duration of the review period, although this location was sampled on a monthly basis.

Concentrations of ammoniacal nitrogen in the Dulas River and Dulas Valley Spring sampling locations ranged from <0.01mg/l to 0.3mg/l.

Chloride concentrations averaged 24mg/l in all sampling locations, with a maximum concentration of 68.5mg/l recorded from the Dulas Spring. These concentrations are significantly below the UK DWS limit of 250mg/l.

Results of Mercury were reported ranged from <0.005ug/l to 0.02ug/l, and lead results ranged from <0.001mg/l to 0.006mg/l throughout the review period.

Mecoprop concentrations averaged 0.0147ug/l for the 3 surface water sampling locations, with a maximum concentration of 0.14ug/l recorded in the Dulas Valley Spring in January 2019. The following month it reduced to 0.05ug/l, the below the limit of detection in March 2019.

To summarise, there have been no emissions of site derived surface water run off through the W1 discharge point during the review period. All other sampling locations have shown no evidence to suggest any kind of environmental impact on the localised water courses that could be attributed to landfilling activities at Llanddulas.

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6.0 EMISSIONS TO AIR

6.1 Flux Box/FID Surveys

The Site Permit states that the Operator shall ensure that all appropriate measures are taken to prevent or where that is not practicable to reduce fugitive emissions to air from:

- open surfaces, unfilled, operational and filled landfill surfaces;
- storage areas
- buildings
- pipes, valves and other transfer systems.

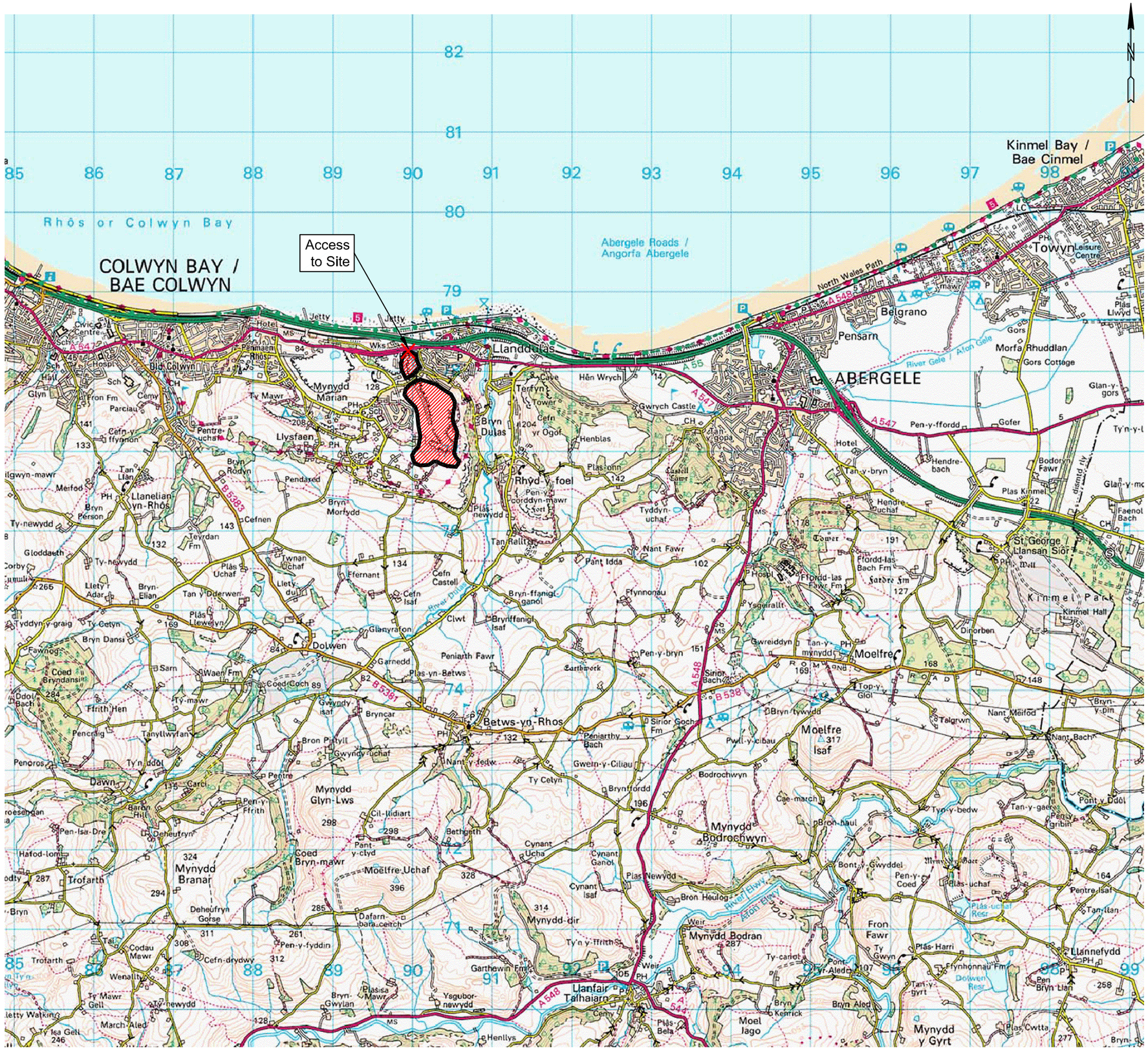
Emissions to air are monitored in accordance with the requirements of Tables S4.6 & S4.11 of the Site Permit. A monthly walkover survey of the landfill and all infrastructure is carried out on a monthly basis using a TDL-500 Gazomat Inspectra Laser methane leak detector machine. Details of any exceedances found are reported to NRW and included in the quarterly reports using the TDL breach tracker. Any exceedances of 1000ppm at any point of infrastructure are remediated the same month via co-ordination between FCC and Infinis, with action plans developed and closed out accordingly.

A monthly perimeter survey of the site is also completed using an FID machine, of which no breaches of assessment limits have been seen throughout the review period.

Quarterly Jerome surveys, concentrating specifically on detection of hydrogen sulphide, were conducted on a monthly basis throughout the review period, again recording no concentrations approaching any assessment limit.

A full site flux box survey was carried out during 2018 and is appended to this report.

DRAWING 1



Llanddulas Landfill Site
Abergele
Clwyd
LL22 8PH
Tel: 01492 518248

5km east of Colwyn Bay, North Wales
Site centred N.G.R. SH903776

REVISIONS				
No	Description	By	Chk'd	Date
A	Titlebox updated.	CMD	CJM	07.07.04

Project:

LLANDDULAS
LANDFILL SITE

Title:

Site Location Plan

Drawn By	JRP	Date	21.06.01
Chk'd By	CJM	Date	21.06.01
Scale 1:	50,000	Sheet Size	A3

Waste Recycling Group
3 Sidings Court
White Rose Way
Doncaster
DN4 5NU

Drawing No
122T020A

DRAWING 2

LEGEND

- Ownership Boundary
- Landfill Gas Monitoring Borehole
- Landfill Gas Surface Monitoring Point
- Combined Gas/ Groundwater Monitoring Point
- Gas Flare Stack
- Landfill Gas Extraction/ Leachate Monitoring Point
- Condensate Unit (Knock-out Pot)
- Gas Manifold
- Groundwater Monitoring Borehole
- Groundwater Pumping Point
- Surface Water Monitoring Point
- Leachate Collection Point
- Leachate Monitoring Point
- Leachate Recirculation Point
- Leachate Collection Sump
- Leachate Discharge Sampling Point
- Leachate Detection Point
- Underdrainage Monitoring Point
- Site Investigation Borehole
- Soakaway
- Drain/ Dewatering Tank
- Valve
- As-built Cell Footprint

Files Used:

Site Survey: 122E1490
Monitoring Plan: 122M1126
Cell Footprints: 122B014

REVISIONS				
No	Description	By	Chk'd	Date
A	Well Detail Updated	LH	GF	12.06.14

Project:

LLANDDULAS
LANDFILL SITE

Title:

Environmental Monitoring Plan

Drawn By	LH	Date	28.05.14
Chk'd By	GF	Date	28.05.14
Scale 1:	2500	Sheet Size	A1

FCC Environment (UK Limited)
3 Sidings Court
White Rose Way
Doncaster
DN4 5NU

FCC Environment (UK Limited)
3 Sidings Court, White Rose Way, Doncaster, DN4 5NU

Drawing No
122M264

Plan 4A

Last Saved By: Lizelle Hunter Date: 12-Jun-14 Plot By: lizelle hunter Date: 12-Jun-14

APPENDIX 1

Site: **Llanddulas**

Permit: **BP 3734 XX**

Reporting period: **6th February 2018 - 6th February 2019**

Test date: **07-Dec-18**

Engine Emission Data

	Species	Method description		Measurement uncertainty (+ or - %)	Average measured emission concentration (mg/Nm3)	LFTGN08 overall uncertainty (+ or - %)	Maximum emission including uncertainty (mg/Nm3)	Minimum emission including uncertainty (mg/Nm3)	Permit emission standard (mg/Nm3)
Engine 1 (A2)	NOx	Chemiluminescence	BS EN 14792	3.1	596	30	775	417	650
	CO	IR	BS EN 15058	2.3	1,352	20	1622	1082	1,500
	TVOC	FID	BS EN 12619	4.5	1,150	40	1610	690	1,750
Engine 2 (A3)	Species	Method description		Measurement uncertainty (+ or - %)	Average measured emission concentration (mg/Nm3)	LFTGN08 overall uncertainty (+ or - %)	Maximum emission including uncertainty (mg/Nm3)	Minimum emission including uncertainty (mg/Nm3)	Permit emission standard (mg/Nm3)
	NOx	Chemiluminescence	BS EN 14792	3.4	438	30	569	307	650
	CO	IR	BS EN 15058	2.2	1,497	20	1796	1198	1,500
	TVOC	FID	BS EN 12619	4.5	1,589	40	2225	953	1,750
Engine 3 (A4)	Species	Method description		Measurement uncertainty (+ or - %)	Average measured emission concentration (mg/Nm3)	LFTGN08 overall uncertainty (+ or - %)	Maximum emission including uncertainty (mg/Nm3)	Minimum emission including uncertainty (mg/Nm3)	Permit emission standard (mg/Nm3)
	NOx	Chemiluminescence	BS EN 14792	na	see note 4	30	na	na	650
	CO	IR	BS EN 15058	na	see note 4	20	na	na	1,500
	TVOC	FID	BS EN 12619	na	see note 4	40	na	na	1,750

Note 1 All data is expressed as mg/Nm3 at 273K, 101.3kPa, dry gas, corrected to an oxygen content of 5%. Average measured emissions concentration is calculated from data collected over a one hour period.

Note 2 The monitoring and reporting were carried out by Socotec, an MCERTS accredited contractor. Staff attending: L Mason Team Leader Level 2 with TE1, TE2, TE3 and TE4. M Derbyshire Level 1 with TE1, TE2 and TE4.

Note 3 Measurement uncertainty is shown. Overall site uncertainty could not be deduced from available data - maximum uncertainty values set out in LFTGN08 have therefore been applied.

Note 4 Engine 3 (A4) was removed from site in January 2016. Available landfill gas is normally controlled by the two remaining engines.

Note 5 All measured parameters on both engines met permit requirements.

Note 6 Neither flare has run for more than 10% of the time over the previous 12 months, therefore testing was not required (standby flares).

INFINIS ENERGY SERVICES LIMITED

Periodic monitoring of raw landfill gas

Llanddulas Landfill Site

Report	LNO14637-TG
Date	21 December 2018
Issue	1

1015

PERIODIC MONITORING OF RAW LANDFILL GAS

LLANDDULAS LANDFILL SITE

Report prepared for

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Issue history

Issue	Date	Approved	
LNO14637-TG, 1	21 December 2018	N Ford	N Ford
First issue			

1 Introduction

Infinis Energy Services Limited (Infinis) contracted SOCOTEC UK Limited (SOCOTEC) to undertake monitoring of the landfill gas supply to its combustion operations at the Llanddulas Landfill site.

2 Test methodology

Infinis requested that duplicate samples of landfill gas be collected and analysed for the priority trace components (LFGTGN04, Table 1.1) specified in Environment Agency guidance (Guidance for monitoring trace components in landfill gas – LFGTGN04 v3.0, 2010). The test methodology should be in accordance with that specified within LFGTGN04.

Based on LFGTGN04 the priority trace gas components are sampled using a combination of four sampling media as shown in Table 1.

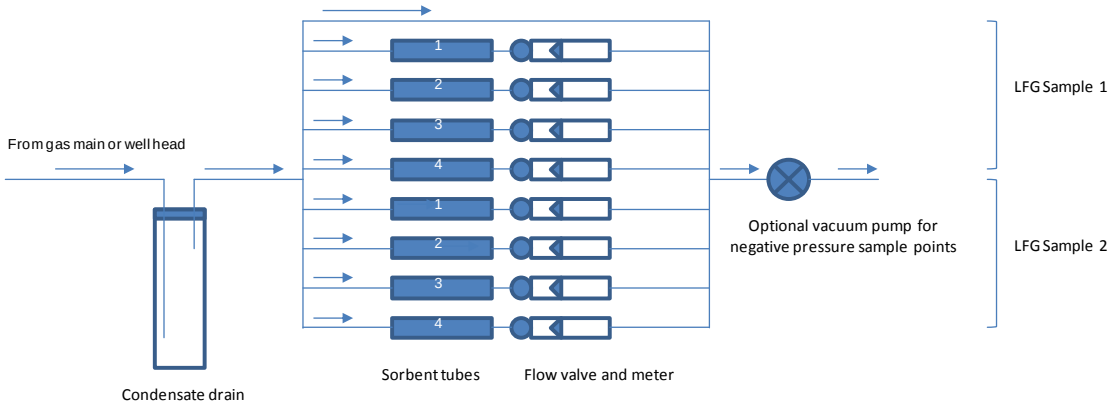
Table 1 Sampling media and analytical methods

Trace component	CAS number	Sampling method	Analytical method
1,1-dichloroethane	75-34-3	Dual solid sorbent	ATD-GC-MS
1,2-dichloroethane	107-06-2	Dual solid sorbent	ATD-GC-MS
1,1-dichloroethene	75-35-4	Dual solid sorbent	ATD-GC-MS
1,2-dichloroethene	540-59-0	Dual solid sorbent	ATD-GC-MS
1,3-butadiene	106-99-0	Dual solid sorbent	ATD-GC-MS
1-butanethiol	109-79-5	Dual solid sorbent	ATD-GC-MS
1-pentene	109-67-1	Dual solid sorbent	ATD-GC-MS
1-propanethiol	107-03-9	Dual solid sorbent	ATD-GC-MS
2-butoxyethanol	111-76-2	Dual solid sorbent	ATD-GC-MS
Arsenic (as As)	7440-38-2	Charcoal	ICP-MS
Benzene	71-43-2	Dual solid sorbent	ATD-GC-MS
Butyric acid	107-92-6	Dual solid sorbent	ATD-GC-MS
Carbon disulphide	75-15-0	Dual solid sorbent	ATD-GC-MS
Chloroethane	75-00-3	Dual solid sorbent	ATD-GC-MS
Chloroethene (vinyl chloride)	75-01-4	Dual solid sorbent	ATD-GC-MS
Dichloromethane	75-09-2	Dual solid sorbent	ATD-GC-MS
Dimethyl disulphide	624-92-0	Dual solid sorbent	ATD-GC-MS
Dimethyl sulphide	75-18-3	Dual solid sorbent	ATD-GC-MS
Ethanal (acetaldehyde)	75-07-0	Silica gel/2,4 DNPH	HPLC-DAD
Ethanethiol	75-08-1	Dual solid sorbent	ATD-GC-MS
Ethyl butyrate	105-54-4	Dual solid sorbent	ATD-GC-MS
Furan (1,4-epoxy-1,3-butadiene)	110-00-9	Dual solid sorbent	ATD-GC-MS
Hydrogen sulphide	7783-06-4	Charcoal	IC
Methanal (formaldehyde)	50-00-0	Silica gel/2,4 DNPH	HPLC-DAD
Methanethiol	74-93-1	Dual solid sorbent	ATD-GC-MS
Styrene	100-42-5	Dual solid sorbent	ATD-GC-MS
Tetrachloromethane	56-23-5	Dual solid sorbent	ATD-GC-MS
Toluene	108-88-3	Dual solid sorbent	ATD-GC-MS
Trichloroethene	79-01-6	Dual solid sorbent	ATD-GC-MS

ATD – automated thermal desorption
GC-MS – gas chromatography and mass spectrometry
ICP-MS – inductively couple plasma/mass spectrometry
HPLC-DAD – high performance liquid chromatography and diode array detection
IC – ion chromatography

Sampling for all components is undertaken simultaneously using a multiple stream sampler as shown in Figure 1.

Figure 1 Landfill gas sampling arrangement



A sample is taken from either the gas main or well head and passed through a condensate drain to remove excess moisture. The sample gas is then split to pass through a series of eight regulated rotameters arranged in two banks of four. There is also a bypass stream for excess sample. This allows the duplicate simultaneous sampling at regulated flow rates onto four sampling media. The flow rates and sampling duration are set in accordance with LFGTGN04 requirements as summarised in Table 2.

Table 2 Sampling media and analytical methods

Media	Target species	Sampling rate (ml/min)	Sampling duration (min)	Sample volume (l)
Dual solid sorbent (Tenax/Sulficarb)	VOCs	20	10	0.2
Silica gel and 2,4 DNPH (SKC 226-119)	Aldehydes	20	50	1.0
Activated carbon 1 (SKC 226-09)	Arsenic	100	50	5.0
Activated carbon 2 (SKC 226-09)	Hydrogen sulphide	100	50	5.0

In the case of negative pressure sources it is necessary to employ a vacuum pump at the sampler's common outlet. This is not normally required with positive pressure systems

This results in two duplicate samples of landfill gas with each sample comprising the four sub-samples above covering all of the priority trace components within Table 1.

The samples are subject to the analytical procedures described in Table 1 to provide a mass on the collected sample which can then be related to the volume of gas sampled to provide a component concentration in the sampled landfill gas.

The sampling followed internal procedure GAS14 and is accredited under test certificate 1015.

3 Site information

Sample point details			
Date	7 December 2018	Site	Llanddulas landfill site
Ambient temperature	6 °C	Atmospheric pressure	101.0 kPa
Monitoring organisation	SOCOTEC UKAS 1015	Analytical laboratory	SOCOTEC UKAS 1015
Location of sampling point	Gas main to compound After blower	Area of influence of collection system sampled	All
Type of sample point	¼" Tefen	Temperature of gas	Not recorded
Pressure at sample point	Not recorded	Type of waste	Not recorded
Status of gas system	Active	Age of waste	Not recorded

4 Preliminary checks and field measurements

Parameter		Concentration
Methane	%	45.8
Carbon dioxide	%	33.1
Oxygen	%	1.3
Nitrogen (by difference)	%	19.8
Hydrogen sulphide	ppmv	180
Carbon monoxide	ppmv	10

*carbon monoxide is measured with a hydrogen sulphide filter in the sampling line.

Preliminary bulk gas measurements were undertaken using a GFM 436 electrochemical cell analyser (no 12704). Reported measurements are spot readings following gas sampling for a period of 5 minutes.

5 Results of landfill gas analysis

The results of the sampling and analysis are summarised in Table 3 below.

Table 3 Priority trace component measurement results

Parameter		Concentration (µg/m^3,STP)
1 Pentene		205
1,1-Dichloroethane		51
1,1-Dichloroethylene		<46
1,2-Dichloroethane		358
1,2-Dichloroethylene		<26
1,3-Butadiene		<36
1,4 epoxy 1,3 butadiene		205
1-Propanethiol		<102
2-butoxyethanol		<102
Benzene		4553
Butyric acid		<205
Carbon disulphide		1586
Carbon tetrachloride		<51
Chloroethane		<51
Dichloromethane		819
Dimethyl disulphide		51
Dimethyl sulphide		256
Ethyl butyrate		51
Ethyl mercaptan		<153
Methyl mercaptan		<512
N-Butyl mercaptan		<153
Styrene		153
Toluene		11255
Trichloroethylene		102
Vinyl chloride monomer		460
Arsenic		72
Hydrogen sulphide		157569
Acetaldehyde	*	205
Formaldehyde	*	<102

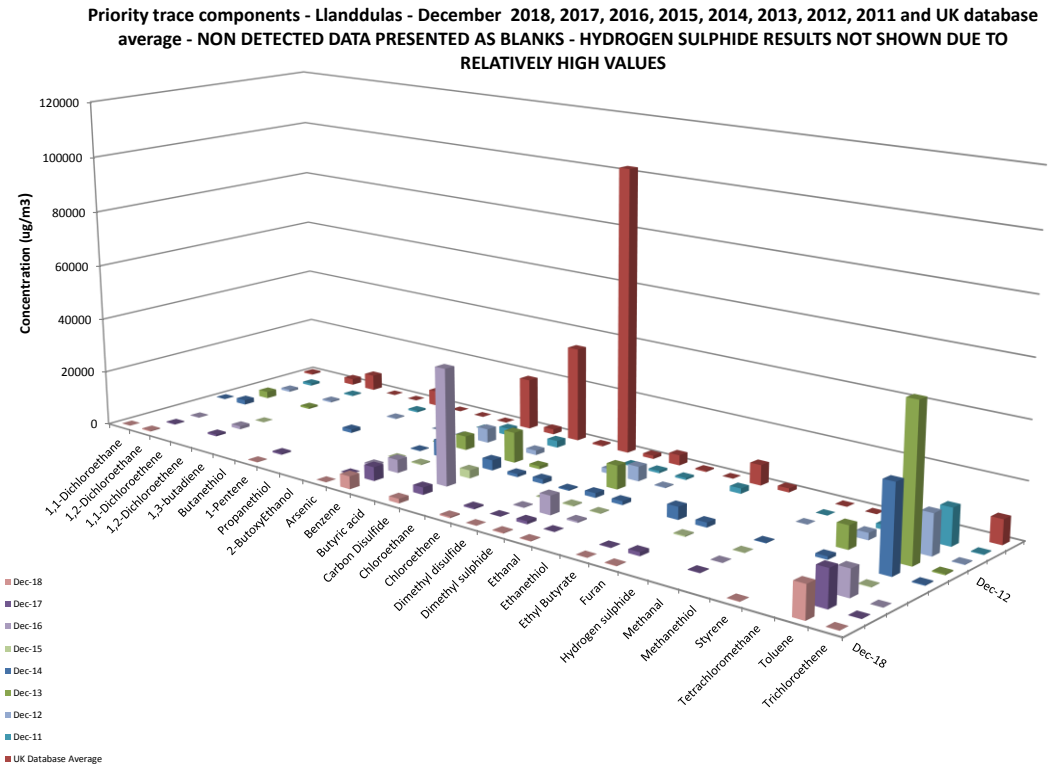
* indicates result is UKAS accredited

< indicates result is below the method limit of detection

The above reported results are the maximum concentrations measured for each parameter in two samples.

The maximum results of the current analyses are compared with historical data and the UK database average in Figure 2.

Figure 2 Historical priority trace component analysis results at Llanddulas



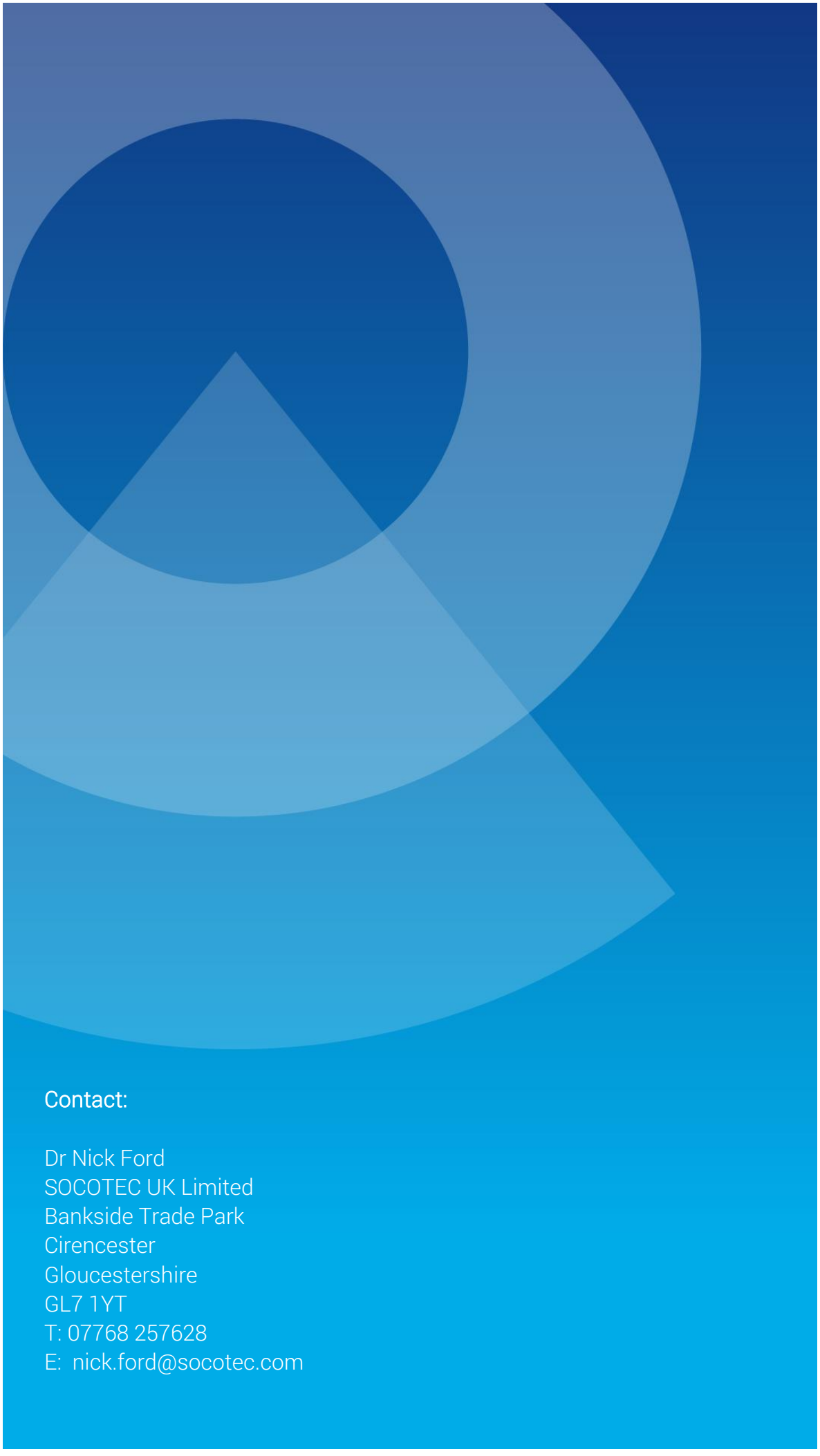
6 Notes

Sampling of landfill gas was undertaken in accordance with SOCOTEC procedure GAS14 and is UKAS accredited under certificate 1015.

Analysis of collected samples was undertaken by SOCOTEC's Bretby laboratory. The analytical results which fall within SOCOTEC's scope of accreditation under certificate 1015 are identified in Table 3.

The priority component measurements which can be considered to be within the scope of UKAS accreditation are identified in Table 3.

Any interpretations and opinions expressed are outside of the scope of UKAS accreditation.



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APPENDIX 2

Flux Box Survey Report

Llanddulas Landfill Site

May 2018

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Approval Sheet

Customer: FCC Environment

Site: Llanddulas Landfill Site

Project title: Flux Box Survey

Project Manager: G White

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Issue	Status	Date	Prepared By	Signature	Date
1	Final	21/06/2018	C Keightley	C Keightley	17/06/2018
			Approved By	**Signature**	**Date**
			G White	G White	18/06/2018

Foreword

enitial has used its best endeavours, experience and expertise to provide a meaningful, accurate and relevant representation of the works carried out. The works were based on a defined programme and scope of works and terms and conditions agreed with the Client.

The findings discussed in this document relating to information provided by the Client relate only to those to which we have had access. No attempt has been made to validate any data or information provided. It is acknowledged that certain aspects may be superseded or rendered irrelevant by information in documentation to which we have not accessed.

enitial cannot accept responsibility to any parties whatsoever, following the issue of this report, for any matters arising which may be considered outside the agreed scope of works.

This report is issued solely to the Client. enitial does not accept any responsibility to any third parties to whom this report may be circulated, in part or in full, and any such parties rely on the contents at their own risk.

Contents

Appendix

1.0 Introduction

1.1 Brief

enitial were commissioned by FCC Environment (FCC) to undertake a Surface Emissions Phase 2 (Flux Box) Survey at their Llanddulas Landfill Site in May 2018. Llanddulas Landfill Site is situated off Abergele Lane, near the village of Llanddulas, in Conwy at NGR SH903775. The site is currently operational and accepting waste inputs, some areas of the site have been permanently capped.

1.2 Desk Study

A desktop study was undertaken prior to the Flux Box Survey by collecting information supplied by FCC in the form of drawings of capping areas and up to date topography. Two zones were identified as requiring Flux Box Surveying, both of which comprised of permanent welded geomembrane capping.

2.0 Survey Summary

2.1 Flux Box Survey

The Flux Box Survey was undertaken on 29, 30 and 31 May 2018 and included the capped and restored areas of the landfill site as indicated on the plan contained in Appendix B.

The required number of test locations was calculated to be 85 during the desktop study. Co-ordinates were generated for each test and each location was set out by the use of a handheld GPS with a typical accuracy of up to 3m. Where a test location was not accessible or unsuitable, the nearest practical location was used and the revised co-ordinates recorded. The flux box used was constructed using a white plasterer's bath with a quick release monitoring point. The flux box was then placed onto the surface and adequately sealed in addition to placing a weight on top of the flux box. Each location was tested for a duration of 15 minutes by connecting the Gas-Tec FID to the flux box monitoring point, with any concentration increases recorded at 30 second intervals for the first 5 minutes and at 1 minute intervals for the remainder of the test.

3.0 Results Summary

3.1 Flux Box Survey Results

A full set of Flux Box Survey results are presented in Appendix A along with a plan showing the location of each test in Appendix B.

The EA Guidance sets standards for gas emissions from a landfill surface which is expressed as the average flux of methane from the surface of the cap in each zone. The emission standard for a permanently capped zone is 0.001mg/m^2/second.

As can be seen from the table below, the average flux of methane from the surface of the cap in Zone 1 is within the EA standards. The average flux of methane from the surface of the cap in Zone 2 exceeds the EA standards detailed above.

Zone	Capping Type	EA Standard for Capping Type (mg/m^2/sec)	Average Q Value for Zone (mg/m^2/sec)	Within EA Standards (Y/N)
1	Permanent	0.001	0.00015	Y
2	Permanent	0.001	0.00102	N

Flux Box test location Z1/32 was moved due to the location being too steep, Flux Box test location Z2/07 and Z2/19 were moved due to machinery working in the area and Flux Box test location Z2/27 was moved due to the location being overgrown.

The primary cause of Zone 2 exceeding the EA standards is due to Flux Box test location Z2/09 which showed readings of 100ppm after 5 minutes of the Flux Box test – the surface was noted as being cracked around this point.

3.2 Notes on Calculation of Flux and Average Q Values

Data points used in the calculation of the Q values are shown as highlighted yellow in the tables presented in Appendix A. The concentration change is converted into mg/m^3 by multiplying the ppm value by 0.714 (source - EA Guidance). The volume of the flux box used is 0.16m^3 with a basal area of 0.65m^2.

In order to obtain data with a high correlation coefficient (preferably $r^2 \geq 0.8$) some data points may be removed at the calculation stage (as detailed in Section 7.2 of the EA Guidance). In addition, an assessment is made to determine what data is considered most representative for that test location and which data will be used in the Q value calculation.

Where data used does not achieve an r^2 value of ≥0.8, the location is reported as being 'at the limit of detection' and as detailed above the data that is considered the most representative for that test location is used, subject to the possibility of retesting the location depending on the overall / average Q value for that zone, i.e. if the emission rate for that location is not likely to significantly affect the overall average Q value of the zone then retesting is not deemed necessary.

Where no elevated readings are detected (or the change in concentration is zero, or a negative change in concentration is recorded at locations when an initial zero reading cannot be attained due to elevated background readings), the location is reported as being less than the lower detection limit value of 5×10^{-5} mg/m^2/second for the flux box used.

4.0 Field Log

4.1 Weather Conditions and Meteorological Data

Meteorological data was recorded from on site observations and local weather station data. The table below details conditions and observations made during the survey.

Date / Time Period	Weather Conditions	Ground Conditions	Temperature (°C)	Atmospheric Pressure (mbar)	Wind Direction / Speed (mph)
29/05/2018 10:00	Sunny	Dry	19	1021	E / 6
29/05/2018 14:30	Sunny	Dry	22	1019	N / 8
30/05/2018 07:30	Cloudy	Dry	13	1015	ESE / 1
30/05/2018 15:00	Cloudy	Dry	16	1014	NE / 3
31/05/2018 07:30	Cloudy	Moist	16	1014	ESE / 5
31/05/2018 11:30	Cloudy	Moist	20	1015	ESE / 5

4.2 Site Personnel and Equipment

The table below details the personnel on site during the survey and the equipment type used including serial number and calibration expiry details.

Date	Personnel	Instrument Type	Instrument Serial Number	Calibration Due	Flux Box Reference
29/05/2018	J Kanhimbe	Gas-Tec FID	6154	02/09/2018	UNK
29/05/2018	D Clarke	Gas-Tec FID	8039	22/09/2018	UNK
30/05/2018	J Kanhimbe	Gas-Tec FID	6154	02/09/2018	UNK
30/05/2018	D Clarke	Gas-Tec FID	8039	22/09/2018	UNK
31/05/2018	J Kanhimbe	Gas-Tec FID	6154	02/09/2018	UNK

Date	Personnel	Instrument Type	Instrument Serial Number	Calibration Due	Flux Box Reference
31/05/2018	D Clarke	Gas-Tec FID	8039	22/09/2018	UNK

Appendix A

Flux Box Survey Results

Llanddulas Landfill Site
Flux Box Survey Calculations - Zone 1
May 2018

ID	Date	Location		Concentration in mg/m^3 over time in seconds																					Linear Regression		V/A (V = 0.16m^3, A = 0.65m^2)	Flux (Q) in mg/m^2/second (Q = V/A x (dc/dt))	Comments
		E	N	0	30	60	90	120	150	180	210	240	270	300	360	420	480	540	600	660	720	780	840	900	r^2 value	dc/dt			
Z1/01	29/05/2018	290100	377904	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	N/A	0.000	0.246	0.00000	No concentration increase (<LOD)
Z1/02	29/05/2018	290139	377904	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	0.737	0.003	0.246	0.00075	At limit of detection *
Z1/03	29/05/2018	290178	377904	0.7	0.7	0.7	0.7	0.7	0.7	1.4	1.4	1.4	1.4	1.4	1.4	2.1	2.1	2.1	2.9	2.9	2.9	2.9	2.9	2.9	0.928	0.003	0.246	0.00072	r2 > 0.8
Z1/04	29/05/2018	290103	377865	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.000	0.246	0.00000	Below limit of detection
Z1/05	29/05/2018	290139	377865	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.000	0.246	0.00000	Below limit of detection
Z1/06	29/05/2018	290178	377865	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.000	0.246	0.00000	Below limit of detection
Z1/07	29/05/2018	290217	377865	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.000	0.246	0.00000	Below limit of detection
Z1/08	29/05/2018	290139	377826	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.000	0.246	0.00000	Below limit of detection
Z1/09	29/05/2018	290178	377826	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.000	0.246	0.00000	Below limit of detection
Z1/10	29/05/2018	290217	377826	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.000	0.246	0.00000	Below limit of detection
Z1/11	29/05/2018	290256	377826	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.000	0.246	0.00000	Below limit of detection
Z1/12	29/05/2018	290295	377826	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.000	0.246	0.00000	Below limit of detection
Z1/13	29/05/2018	290178	377787	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.000	0.246	0.00000	Below limit of detection
Z1/14	29/05/2018	290217	377787	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.000	0.246	0.00000	Below limit of detection
Z1/15	29/05/2018	290256	377787	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.000	0.246	0.00000	Below limit of detection
Z1/16	29/05/2018	290295	377787	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.000	0.246	0.00000	Below limit of detection
Z1/17	29/05/2018	290334	377787	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.000	0.246	0.00000	Below limit of detection
Z1/18	29/05/2018	290256	377748	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.000	0.246	0.00000	Below limit of detection
Z1/19	29/05/2018	290295	377748	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.000	0.246	0.00000	Below limit of detection
Z1/20	29/05/2018	290334	377748	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.000	0.246	0.00000	Below limit of detection
Z1/21	29/05/2018	290373	377748	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.000	0.246	0.00000	Below limit of detection
Z1/22	29/05/2018	290412	377748	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.000	0.246	0.00000	Below limit of detection
Z1/23	30/05/2018	290217	377709	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.000	0.246	0.00000	Below limit of detection
Z1/24	30/05/2018	290256	377709	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.000	0.246	0.00000	Below limit of detection
Z1/25	30/05/2018	290295	377709	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.000	0.246	0.00000	Below limit of detection
Z1/26	30/05/2018	290334	377709	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.000	0.246	0.00000	Below limit of detection
Z1/27	30/05/2018	290373	377709	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.000	0.246	0.00000	Below limit of detection
Z1/28	30/05/2018	290412	377709	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.000	0.246	0.00000	Below limit of detection
Z1/29	30/05/2018	290451	377709	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.000	0.246	0.00000	Below limit of detection
Z1/30	30/05/2018	290488	377709	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.000	0.246	0.00000	Below limit of detection
Z1/31	30/05/2018	290217	377670	0.0	0.0	0.0	0.7	1.4	1.4	1.4	1.4	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	0.818	0.006	0.246	0.00150	r2 > 0.8
Z1/32	30/05/2018	290286	377670	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	1.4	1.4	1.4	1.4	1.4	0.857	0.002	0.246	0.00044	r2 > 0.8
Z1/33	30/05/2018	290334	377670	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.000	0.246	0.00000	Below limit of detection
Z1/34	30/05/2018	290373	377670	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.000	0.246	0.00000	Below limit of detection
Z1/35	30/05/2018	290412	377670	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.000	0.246	0.00000	Below limit of detection
Z1/36	30/05/2018	290451	377670	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.000	0.246	0.00000	Below limit of detection
Z1/37	30/05/2018	290490	377670	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.000	0.246	0.00000	Below limit of detection
Z1/38	30/05/2018	290256	377631	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	N/A	0.000	0.246	0.00000	No concentration increase (<LOD)
Z1/39	30/05/2018	290373	377631	0.0	0.0	0.7	0.7	0.7	0.7	0.7	1.4	1.4	1.4	2.1	2.1	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	0.821	0.003	0.246	0.00085	r2 > 0.8
Z1/40	30/05/2018	290412	377631	0.0	0.7	0.7	1.4	1.4	1.4	1.4	0.7	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.840	0.010	0.246	0.00234	r2 > 0.8
Z1/41	30/05/2018	290451	377631	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.000	0.246	0.00000	Below limit of detection
Z1/42	30/05/2018	290256	377592	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.000	0.246	0.00000	Below limit of detection
Z1/43	30/05/2018	290295	377592	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.000	0.246	0.00000	Below limit of detection
Z1/44	30/05/2018	290334	377592	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.000	0.246	0.00000	Below limit of detection

Llanddulas Landfill Site
Flux Box Survey Calculations - Zone 1
May 2018

ID	Date	Location		Concentration in mg/m^3 over time in seconds																					Linear Regression		V/A (V = 0.16m^3, A = 0.65m^2)	Flux (Q) in mg/m^2/second (Q = V/A x (dc/dt))	Comments
		E	N	0	30	60	90	120	150	180	210	240	270	300	360	420	480	540	600	660	720	780	840	900	r^2 value	dc/dt			
Z1/45	30/05/2018	290373	377592	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.000	0.246	0.00000	Below limit of detection

Co-ordinates shown in blue denote monitoring point moved from original design GPS co-ordinates to nearest suitable location

Zone 1 (Permanent Cap) Average Q Value **0.00015** **mg / m^2 / second**

*Refer to notes on Linear Regression Calculations and Final Q Values and:

Where data is 'at the limit of detection' of the flux box used, i.e. the r2 value of >0.8 could not be attained following data point removal, the data with the highest r2 value or data that is considered most representative of the overall test is used following assessment of such data

Llanddulas Landfill Site
Flux Box Survey Calculations - Zone 2
May 2018

ID	Date	Location		Concentration in mg/m^3 over time in seconds																					Linear Regression		V/A (V = 0.16m^3, A = 0.65m^2)	Flux (Q) in mg/m^2/second (Q = V/A x (dc/dt))	Comments
		E	N	0	30	60	90	120	150	180	210	240	270	300	360	420	480	540	600	660	720	780	840	900	r^2 value	dc/dt			
Z2/01	30/05/2018	290513	377603	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.000	0.246	0.00000	Below limit of detection
Z2/02	30/05/2018	290376	377567	3.6	3.6	4.3	4.3	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.7	5.7	5.7	5.7	5.7	5.7	6.4	6.4	6.4	6.4	0.856	0.003	0.246	0.00069	r2 > 0.8
Z2/03	30/05/2018	290412	377567	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	0.737	0.002	0.246	0.00038	At limit of detection *
Z2/04	30/05/2018	290448	377567	5.0	5.0	5.0	4.3	4.3	3.6	3.6	3.6	2.9	2.9	2.9	2.9	2.9	2.9	2.1	2.1	2.1	2.1	2.1	2.1	2.1	N/A	0.000	0.246	0.00000	No concentration increase (<LOD)
Z2/05	30/05/2018	290484	377567	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	71.4	71.4	71.4	71.4	71.4	71.4	71.4	71.4	71.4	71.4	71.4	0.737	0.152	0.246	0.03754	At limit of detection *
Z2/06	30/05/2018	290268	377531	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.000	0.246	0.00000	Below limit of detection
Z2/07	30/05/2018	290304	377531	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.000	0.246	0.00000	Below limit of detection
Z2/08	30/05/2018	290340	377531	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.000	0.246	0.00000	Below limit of detection
Z2/09	30/05/2018	290318	377531	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.000	0.246	0.00000	Below limit of detection
Z2/10	30/05/2018	290448	377531	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.000	0.246	0.00000	Below limit of detection
Z2/11	30/05/2018	290484	377531	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.000	0.246	0.00000	Below limit of detection
Z2/12	30/05/2018	290520	377531	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.000	0.246	0.00000	Below limit of detection
Z2/13	30/05/2018	290232	377495	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.000	0.246	0.00000	Below limit of detection
Z2/14	30/05/2018	290268	377495	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.000	0.246	0.00000	Below limit of detection
Z2/15	30/05/2018	290304	377495	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.000	0.246	0.00000	Below limit of detection
Z2/16	30/05/2018	290340	377495	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.000	0.246	0.00000	Below limit of detection
Z2/17	30/05/2018	290484	377495	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.000	0.246	0.00000	Below limit of detection
Z2/18	30/05/2018	290520	377495	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.000	0.246	0.00000	Below limit of detection
Z2/19	30/05/2018	290248	377459	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.000	0.246	0.00000	Below limit of detection
Z2/20	30/05/2018	290268	377459	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.000	0.246	0.00000	Below limit of detection
Z2/21	30/05/2018	290484	377459	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.000	0.246	0.00000	Below limit of detection
Z2/22	30/05/2018	290520	377459	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.000	0.246	0.00000	Below limit of detection
Z2/23	30/05/2018	290232	377423	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.000	0.246	0.00000	Below limit of detection
Z2/24	31/05/2018	290268	377423	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.000	0.246	0.00000	Below limit of detection
Z2/25	31/05/2018	290520	377423	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.000	0.246	0.00000	Below limit of detection
Z2/26	31/05/2018	290232	377387	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.000	0.246	0.00000	Below limit of detection
Z2/27	31/05/2018	290460	377387	0.0	0.0	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	0.800	0.003	0.246	0.00075	At limit of detection *
Z2/28	31/05/2018	290484	377387	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.000	0.246	0.00000	Below limit of detection
Z2/29	31/05/2018	290520	377387	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.000	0.246	0.00000	Below limit of detection
Z2/30	31/05/2018	290232	377351	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.000	0.246	0.00000	Below limit of detection
Z2/31	31/05/2018	290304	377351	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.000	0.246	0.00000	Below limit of detection
Z2/32	31/05/2018	290340	377351	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.000	0.246	0.00000	Below limit of detection
Z2/33	31/05/2018	290376	377351	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.000	0.246	0.00000	Below limit of detection
Z2/34	31/05/2018	290412	377351	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.000	0.246	0.00000	Below limit of detection
Z2/35	31/05/2018	290448	377351	0.0	0.0	0.0	0.0	0.0	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.771	0.006	0.246	0.00151	At limit of detection *
Z2/36	31/05/2018	290484	377351	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.000	0.246	0.00000	Below limit of detection
Z2/37	31/05/2018	290268	377315	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.000	0.246	0.00000	Below limit of detection
Z2/38	31/05/2018	290304	377315	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.000	0.246	0.00000	Below limit of detection
Z2/39	31/05/2018	290340	377315	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.000	0.246	0.00000	Below limit of detection
Z2/40	31/05/2018	290376	377317	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.000	0.246	0.00000	Below limit of detection

Co-ordinates shown in blue denote monitoring point moved from original design GPS co-ordinates to nearest suitable location

Zone 2 (Permanent Cap) Average Q Value **0.00102** **mg / m^2 / second**

*Refer to notes on Linear Regression Calculations and Final Q Values and:

Llanddulas Landfill Site
Flux Box Survey Calculations - Zone 2
May 2018

ID	Date	Location		Concentration in mg/m^3 over time in seconds																					Linear Regression		V/A (V = 0.16m^3, A = 0.65m^2)	Flux (Q) in mg/m^2/second (Q = V/A x (dc/dt))	Comments
		E	N	0	30	60	90	120	150	180	210	240	270	300	360	420	480	540	600	660	720	780	840	900	r^2 value	dc/dt			

Where data is 'at the limit of detection' of the flux box used, i.e. the r2 value of >0.8 could not be attained following data point removal, the data with the highest r2 value or data that is considered most representative of the overall test is used following assessment of such data

Appendix B

Flux Box Survey Plan

LEGEND

Fluxbox Survey Zone Boundary

Z1/01 — Fluxbox Test Location & Reference (locations shown in blue denote monitoring point moved from original design GPS co-ordinates to nearest suitable location)

ZONE 1 - PERMANENT CAP (WELDED MEMBRANE)	
AREA:	68,632m2
TESTS REQUIRED:	45
TEST SPACING:	39m

ZONE 2 - PERMANENT CAP (WELDED MEMBRANE)	
AREA:	50,488m2
TESTS REQUIRED:	40
TEST SPACING:	36m

FCC Environment

LLANDDULAS LANDFILL SITE

FLUX BOX SURVEY TEST LOCATION PLAN MAY 2018

DRAWN BY: CK	DATE: 17/06/2018
APPROVED BY:	SCALE @ A3: 1:2500
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