

## Stack Emissions Monitoring Report

commissioned by Mr Edward Vaughan

### Operator Name

Mr Edward Vaughan | Sychtyn

### Operator Address

Llanerfyl  
Welshpool, Powys  
SY21 0JF  
EPR Permit EPR/AB3091ZZ

### Release Point

AD Plant Engine Exhaust

### Monitoring Organisation Name & Address

Atesta Ltd  
Unit 2, Asher Court, Lyncastle Way  
Appleton, Warrington  
WA4 4ST

### Monitoring Report Written By

Rob Haworth | Senior Team Leader  
MCERTS Level 2 | MM 07 797 | TE1 TE2 TE3 TE4 | expires on 31/12/2023

### Monitoring Report Approved By

Chris Rhodes | Senior Team Leader  
MCERTS Level 2 | MM 02 117 | TE1 TE2 TE3 TE4 | expires on 31/08/2023



Job Reference: JOB-349

Report Date | Version Number

08/08/2022 | Version 1

Dates of the Monitoring Campaign

28/07/2022

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# Report Contents and Monitoring Objectives

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## Report Contents

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## Monitoring Objective

The monitoring objective was to conduct stack emissions monitoring to demonstrate compliance against a set of emission limit values (ELVs) as specified in the Site's Environmental Permit.

## Special Requirements

There were no special requirements for this monitoring campaign.

## Opinions and Interpretations

Any opinions or interpretations contained within this test report are outside the scope of Atesta's MCERTS / ISO 17025 accreditation.

# Part 1: Executive Summary - Monitoring Results Summary

## Monitoring Results - Summary

test parameter	EXPRESSED AS A CONCENTRATION				EXPRESSED AS A MASS EMISSION				reference conditions	accreditation status
	result	uncertainty (± 95% CI)	limit (ELV)	units	result	uncertainty (± 95% CI)	limit (ELV)	units		
Sulphur Dioxide	43.8	3.8	350	mg/m <sup>3</sup>	25.9	2.3		g/hr	STP, dry, 5% O <sub>2</sub>	MCERTS
Total VOCs (as Carbon) †	1581	632	1000	mg/m <sup>3</sup>	1047	419		g/hr	STP, dry, 5% O <sub>2</sub>	MCERTS
Oxides of Nitrogen (as NO <sub>2</sub> ) †	567	170	500	mg/m <sup>3</sup>	378	113		g/hr	STP, dry, 5% O <sub>2</sub>	MCERTS
Carbon Monoxide †	877	175	1400	mg/m <sup>3</sup>	584	117		g/hr	STP, dry, 5% O <sub>2</sub>	MCERTS
Oxygen	8.3	0.22		% v/v					dry	MCERTS
Stack Gas Water Vapour	11.5	0.22		% v/v					actual	MCERTS
Stack Gas Temperature	457			°C					actual	MCERTS
Stack Gas Velocity	34.7	0.58		m/s					actual	MCERTS
Stack Gas Flow Rate (ACTUAL)	2514	121		m <sup>3</sup> /hr					actual	MCERTS
Stack Gas Flow Rate (REF)	764	36.8		m <sup>3</sup> /hr					STP, dry, 5% O <sub>2</sub>	MCERTS

The stack gas water vapour, temperature, velocity and flow rates in the above table are calculated as an average of all of the results recorded during this monitoring campaign

† The uncertainties stated above are those specified in Table 4.7 (in Section 4.6.1) of EA LFTGN08 v2 2010, and are the “Assumed maximum values for total uncertainty to be applied when assessing compliance of emissions from [landfill gas] engines”. See Appendix 2 of this report for more information.

## Part 1: Executive Summary - Monitoring Results Further Details

### Monitoring Results - Further Details

test parameter	run	EXPRESSED AS A CONCENTRATION				EXPRESSED AS A MASS EMISSION				sampling date   times	run time (mins)	H <sub>2</sub> O (% v/v)	reference conditions
		result	uncertainty (± 95% CI)	limit (ELV)	units	result	uncertainty (± 95% CI)	limit (ELV)	units				
Sulphur Dioxide	R1	43.8	3.8	350	mg/m <sup>3</sup>	25.9	2.3		g/hr	28/07/2022   11:58 - 12:58	60	11.5	STP, dry, 5% O <sub>2</sub>
Total VOCs (as Carbon) †	R1	1581	632	1000	mg/m <sup>3</sup>	1047	419		g/hr	28/07/2022   11:58 - 12:58	60		STP, dry, 5% O <sub>2</sub>
Oxides of Nitrogen (as NO <sub>2</sub> ) †	R1	567	170	500	mg/m <sup>3</sup>	378	113		g/hr	28/07/2022   11:58 - 12:58	60		STP, dry, 5% O <sub>2</sub>
Carbon Monoxide †	R1	877	175	1400	mg/m <sup>3</sup>	584	117		g/hr	28/07/2022   11:58 - 12:58	60		STP, dry, 5% O <sub>2</sub>
Oxygen		8.3	0.22		% v/v					N/A - Concurrent Testing			dry
Velocity & Flow Rate Traverse	R1	34.7	0.58		m/s	2514	121		m <sup>3</sup> /hr	28/07/2022   13:25 - 13:30			actual

† The maximum values for total uncertainty have been applied to the uncertainty for these results to assess results for compliance. See Appendix 2 and LFTGN08 v2, Section 4.6 for more information.

## Part 1: Executive Summary - Monitoring and Analytical Methods

### Monitoring and Analytical Methods

where analysis required

test parameter	MONITORING					ANALYSIS					
	laboratory	accreditation number	technical procedure	reference method	monitoring status	laboratory	accreditation number	analytical procedure	analytical technique	analysis status	accreditation status
Sulphur Dioxide	ATA	10706	TP-10	EN 14791	MCERTS	RPS	0605	C27	IC	MCERTS	MCERTS
Water Vapour	ATA	10706	TP-03	EN 14790	MCERTS	ATA	10706	TP-03	Gravimetric	MCERTS	MCERTS

where analysis not required

test parameter	MONITORING					measurement technique & equipment	accreditation status
	laboratory	accreditation number	technical procedure	reference method	monitoring status		
Total VOCs (as Carbon)	ATA	10706	TP-21a	EN 12619	MCERTS	FID using ThermoFID	MCERTS
Oxides of Nitrogen (as NO <sub>2</sub> )	ATA	10706	TP-22a	EN 14792	MCERTS	Chemiluminescence using Horiba PG-350E	MCERTS
Carbon Monoxide	ATA	10706	TP-22b	EN 15058	MCERTS	NDIR using Horiba PG-350E	MCERTS
Oxygen	ATA	10706	TP-22d	EN 14789	MCERTS	Paramagnetism using Horiba PG-350E	MCERTS
Velocity & Flow Rate Traverse	ATA	10706	TP-04a	EN 16911-1   TR 17078	MCERTS	Pitot Tube, Thermocouple & Thermomanometer	MCERTS

### Summary of Monitoring Deviations (from Appendix 2)

test parameter	run	details of monitoring deviation
All	1	There were no deviations associated with the monitoring employed.

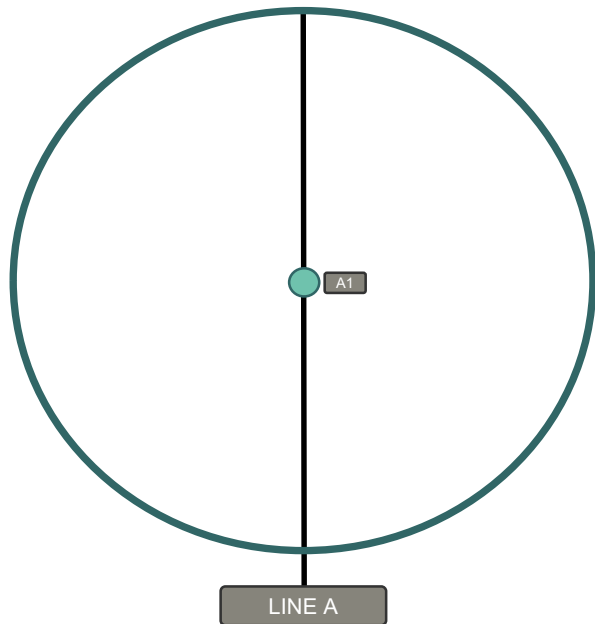
## Part 1: Executive Summary - Monitoring Location

### Monitoring Location Photos



### Identification of Sampling Points on a Duct Diagram

refer to Appendix 2 - Raw Data to see how the points on this diagram relate to the points used for each test



## Part 1: Executive Summary - Duct and Sampling Platform Information

### Duct Characteristics | Sampling Ports

parameter	units	value
shape	-	Circular
dimensions	-	Diameter = 0.16 m
area	m <sup>2</sup>	0.02
orientation	-	Horizontal

parameter	value
primary sample port size	1" BSP
primary sample port depth   cm	10
primary sample ports number of sampling lines available	1

summary of all sample ports available
1" BSP

### Sampling Location General Information

general information	details
type   location   access	On the Ground   Inside plant building   On Ground Level

### CEMS | Abatement Systems

parameter	details
abatement system/s	N/A
CEMS installed on the stack	N/A

### Sampling Plane Validation Criteria Summary (EN 15259) from Stack Traverse/s

criteria in EN 15259	units	value	allowed	compliant
lowest differential pressure	Pa	488.0	> 5 Pa	Yes
lowest traverse velocity	m/s	34.7	-	-
highest traverse velocity	m/s	34.7	-	-
mean traverse velocity	m/s	34.7	-	-
ratio traverse velocities	: 1	1.00	< 3 : 1	Yes
maximum angle of swirl	°	N/A	< 15°	N/A
no local negative flow	-	Yes	-	Yes

## Part 1: Executive Summary - Sampling Location and Operating Information

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### Process Details

process detail	details
plume appearance on day of monitoring	None visible
type of process	Anaerobic Digester Engine
batch or continuous process	Continuous
fuel type	Biogas
feedstock	N/A
typical load / throughput of plant	Normal operation
details of any unusual process occurrences	None

## Part 2: Supporting Information - Appendix 1: Monitoring Personnel, Analysis Laboratories and Test Equipment Used

### Monitoring Personnel

name	position	MCERTS level   number   expiry	MCERTS technical endorsements
Rob Haworth	Senior Team Leader	MCERTS Level 2   MM 07 797   31/12/2023	TE1 TE2 TE3 TE4
Sam Copping	Technician	MCERTS Level 1   MM 21 1653   25/02/2027	-

### Analysis Laboratories

laboratory	ISO 17025 accreditation number	laboratory short name	laboratory phone number
Atesta   North West	10706	ATA	0800 970 8945
RPS Laboratories   Salford	0605	RPS	0161 872 2443

### Test Equipment Used

equipment type	A-EQ ID
Source sampling console	
Low flow sampling MFCs	99   181
ThermoFID / iFID mobile	271
Horiba PG-350E multigas analyser	230
Gasmet DX4000 FTIR	
Gasmet PSS	
Gasmet syringe calibrator	
M&C PSS5-C conditioning unit	66
Digital thermomanometer	114
Mettler Toledo XSR105DU balance	1
Top pan balance kit	42

equipment type	A-EQ ID
Pitot	193
Calipers	35
Barometer	34
Timer	37
Tape measure	25
Heated head filter	62
10m heated line	22   23
1.5m heated line	
Odour barrel	
Vacuum chamber	
Dilution probe	

equipment type	A-EQ ID
10m umbilical	
30m umbilical	
Heated probe	
Filter oven	
Ambient thermocouple	
Stack thermocouple	258
Exit thermocouple	
Condenser thermocouple	
Tubes kit thermocouple	
2-way heater controller	
Air sampling pump	

## Part 2: Supporting Information - Appendix 2: Sulphur Dioxide | Run 1

### Results

reference conditions are: STP, dry, 5% O<sub>2</sub>

parameter	units	result ± MU (95% CI)	units	result ± MU (95% CI)
Sulphur Dioxide	mg/m <sup>3</sup>	43.8 ± 3.8	g/hr	25.9 ± 2.3

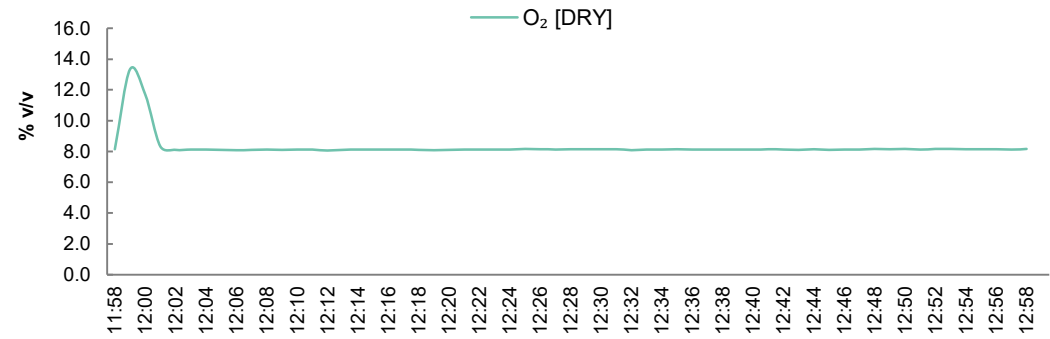
### Analytical Laboratory Information

parameter	details
name of analytical lab	RPS
lab analytical procedure	C27
lab analytical technique	IC   Analysis Accreditation: MCERTS
date analysis completed	04/08/2022

### General Information

parameter	details
sampling date	28/07/2022
sampling times   testing team	11:58 - 12:58   60 minutes   tested by: RH   SC
standard   technical procedure	EN 14791   TP-10
volume metering device	Mass Flow Controller
probe material	Titanium
filter housing material	Stainless Steel Heated Head
impinger material   capture media	Borosilicate Glass   H <sub>2</sub> O <sub>2</sub>

### Oxygen Data



parameter	details
set flow rate	2 l/min
filter size, material & location	Heated Head Filter Element PTFE   Within Heated Head   heated to 180°C
number sampling lines available	1
number sampling lines used	1
number sampling points ideal per line	1
number sampling points used per line	1
sampling point IDs	A1

### Quality Assurance

<sup>2</sup> The concentration in the last absorber was less than 5 times the analytical LOD.

QA parameter	units	sample run			blank (taken on 28/07/2022)		
		value	allowable	result	value	allowable	result
maximum allowable blank	mg/m <sup>3</sup>	-	-	-	0.17	35	Pass
leak test	%	0.59	2.00	Pass	0.57	2.00	Pass
absorption efficiency	%	99.7	N/A <sup>2</sup>	Pass	-	-	-
silica trap <50% faded	-	Yes	-	Pass	-	-	-
are water droplets present	-	No	-	-	-	-	-
water vapour MU	%	2.0	20.0	Pass	-	-	-

### Breakdown of Results

reference conditions are: STP, dry, 5% O<sub>2</sub>

parameter	sample volume [m <sup>3</sup> ]	LOD [mg]	impingers [front   back] [mg/l]	impinger volume [front   back] [ml]	mass total [mg]	LOD result [mg/m <sup>3</sup> ]	result [mg/m <sup>3</sup> ]	result reported [mg/m <sup>3</sup> ]	mass emission [g/hr]
sample run	0.0955	0.024	11.2   0.1	372.3   117.2	4.2	0.26	43.8	<b>43.8</b>	25.9
blank	0.0955	0.016	0.05	319.4	0.016	0.17	0.17	<b>0.17</b>	

## Part 2: Supporting Information - Appendix 2: Sulphur Dioxide | Run 1

### Raw Data | Calculations

data	units	value
P <sub>bar</sub>	mmHg	763.6
P <sub>g</sub>	Pa	75.0
P <sub>s</sub>	mmHg	764.1
V <sub>m</sub> (metered)	m <sup>3</sup>	0.1200
C <sub>stp</sub>	-	0.3592

data	units	value
m <sub>wts</sub>	g	12.6
M <sub>w</sub>	g/mol	18.0
V <sub>mol</sub>	m <sup>3</sup> /mol	0.0222
T <sub>s</sub>	°C	550.0
R <sub>wv</sub> (H <sub>2</sub> O)	% v/v	11.5

data	units	value
%CO <sub>2d</sub>	% v/v (est)	11.50
%O <sub>2d</sub>	% v/v	8.27
%O <sub>2w</sub>	% v/v	7.32
%N <sub>2d</sub>	% v/v	80.23
%O <sub>2ref</sub>	% v/v	5.0
O <sub>2facd</sub>	-	1.26
O <sub>2facw</sub>	-	1.17

data	units	value
M <sub>d</sub>	g/mol	30.17
M <sub>s</sub>	g/mol	28.78
A <sub>s</sub>	m <sup>2</sup>	0.02
θ (sample time)	mins	60

where (est) refers to an estimated value

metered volume calculations	units	value
allow favourable O <sub>2</sub> correction	-	Yes
vol actual stack conditions, V <sub>ma</sub> = (V <sub>mstw</sub> )(T <sub>s</sub> + 273) / (P <sub>s</sub> ) / (C <sub>stp</sub> )	m <sup>3</sup>	0.4063
vol dry, V <sub>mstd</sub> = V <sub>m</sub>	m <sup>3</sup>	0.1200
vol wet, V <sub>mstw</sub> = (V <sub>mstd</sub> )(100 / (100 - R <sub>wv</sub> ))	m <sup>3</sup>	0.1355
vol dry O <sub>2</sub> , V <sub>mstdO<sub>2</sub></sub> = (V <sub>mstd</sub> ) / (O <sub>2facd</sub> )	m <sup>3</sup>	0.0955
vol wet O <sub>2</sub> , V <sub>mstwO<sub>2</sub></sub> = (V <sub>mstw</sub> ) / (O <sub>2facw</sub> )	m <sup>3</sup>	0.1158

velocity   volume flow rate calculations	units	value
velocity of stack gas, v <sub>s</sub> = average of all velocity measurements	m/s	34.7
stack gas flow actual stack conditions, Q <sub>a</sub> = average of all flow rate measurements	m <sup>3</sup> /hr	2514.3

### Measurement Uncertainty (MU) Calculations

parameter	units	value	standard MU	MU as %age	required standard	value	sens coeff.	MU   mg/m <sup>3</sup>
MFC meter volume, V <sub>m</sub>	m <sup>3</sup>	0.1200	0.0006	0.50	≤2%	-	-	-
MFC volume STP, V <sub>mstd</sub>	m <sup>3</sup>	-	-	-	-	0.1	365	0.22
leak, L	% <sup>1</sup>   mg/m <sup>3 2</sup>	1 <sup>1</sup>	-	1.00	≤2%	0.25 <sup>2</sup>	1.00	0.25
laboratory result, L <sub>r</sub>	% <sup>1</sup>   mg/m <sup>3 2</sup>	3.9 <sup>1</sup>	-	3.9	-	1.7 <sup>2</sup>	1.00	1.7
<i>combined MU with O<sub>2</sub> correction</i>								1.9
<i>expanded MU 95% CI with O<sub>2</sub> correction (k = 1.96) including method deviations</i>								3.8
<i>expanded MU 95% CI with O<sub>2</sub> correction (k = 1.96) as percentage of measured value</i>								8.6%
<i>expanded MU 95% CI (k = 1.96) as percentage of measured value for mass emission</i>								9.1%
<i>expanded MU 95% CI with O<sub>2</sub> correction (k = 1.96) as percentage of ELV [allowable 20.4%]</i>								1.1%
								<b>result</b>
								Pass

MU factor O <sub>2</sub> correction
0.05

overall MU for O <sub>2</sub> correction
3.9%

method deviation factor
1.00

method and sampling deviations
Sampling was performed in full compliance with the Standard, technical procedure and regulatory requirements.

## Part 2: Supporting Information - Appendix 2: Total VOCs (as Carbon) | Run 1

### Results

reference conditions are: STP, dry, 5% O<sub>2</sub>

parameter	units	result ± MU (95% CI)	units	result ± MU (95% CI)
Total VOCs (as Carbon) †	mg/m <sup>3</sup>	1581 ± 632	g/hr	1047 ± 419

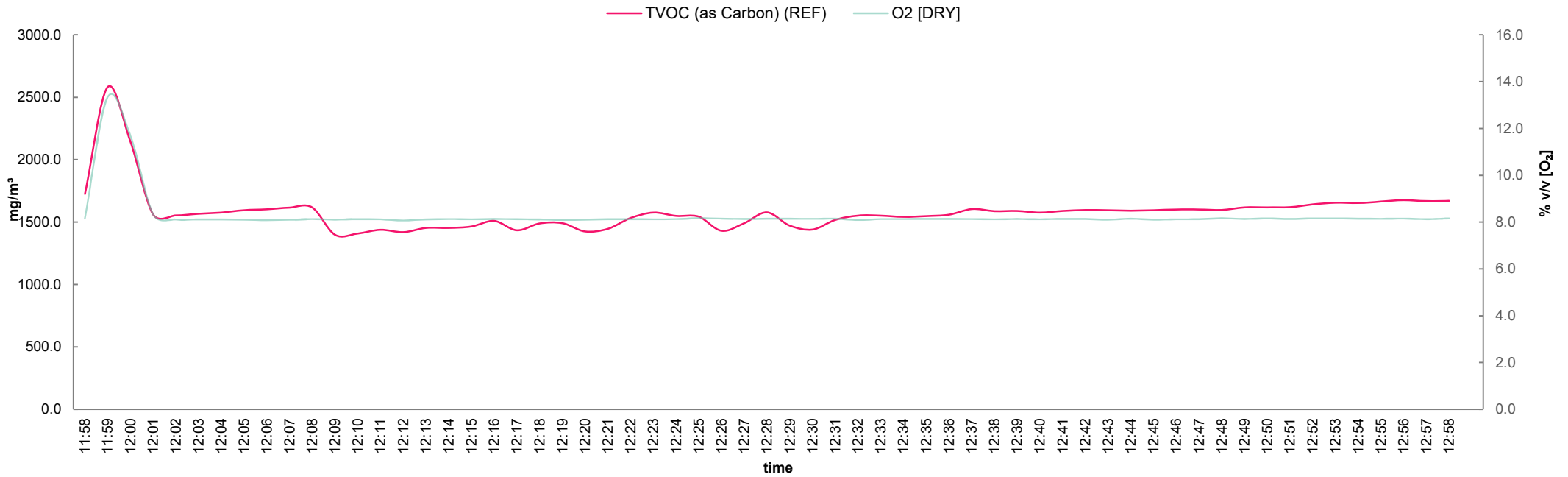
† LFTGN08 maximum value for total uncertainty (40% of measured value) applied to the results

### General Information

parameter	details
sampling start date & time	28/07/2022 11:58
sampling end date & time	28/07/2022 12:58
test time   mins	60
testing team	RH   SC
standard   technical procedure	EN 12619   TP-21a
analyser type	ThermoFID
heated head & line temperature	180°C

parameter	details
probe material	Titanium
filter size, material & location	Filter Element PTFE   Within Heated Head
number sampling lines available	1
number sampling lines used	1
number sampling points ideal per line	1
number sampling points used per line	1
sampling point IDs	A1

### Plot of Emissions Over Time



## Part 2: Supporting Information - Appendix 2: Total VOCs (as Carbon) | Run 1

### Analyser Calibration Information with QA checks

where [A] = at analyser, [L] = down sampling line

CAL ID	pre-test calibration events							post-test calibration events			quality assurance			
	date & time	zero [A] [ppm]	span [A] [ppm]	zero [L] [ppm]	span [L] [ppm]	T <sub>90</sub> [s]	leak [%]	date & time	zero [L] [ppm]	span [L] [ppm]	zero drift [%]	span drift [%]	allowable [%]	temp [°C]

### Analyser Calibration Extended Information

CAL ID	performed by	drift corr. applied	log period [s]	CYL ID	CYL conc. [ppm]	CYL expiry	CYL MU [%]	zero gas type	span [CYL] gas type	span target [ppm]	range [ppm]	LOD [ppm]
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## Part 2: Supporting Information - Appendix 2: Total VOCs (as Carbon) | Run 1

### Measurement Uncertainty (MU) Calculations

general information	units	value
emission limit value (ELV) (REF)	mg/m <sup>3</sup>	1000
measured concentration (REF)	mg/m <sup>3</sup>	1581

MU budget			
parameter	units	min	max
ambient temp	°C	0.0	0.0
voltage	V	90.0	130.0

overall MU for O <sub>2</sub> correction
3.9%

MU factor O <sub>2</sub> correction
0.05

performance characteristics	MU budget input parameters				MU budget			result			
	symbol	units	value	source	symbol	units	value				
repeatability at zero	rz	% of value	0.2	MCERTS certificate MC050062	U <sub>rz</sub>	mg/m <sup>3</sup>	3.2				
repeatability at span	rs	% of value	0.2	MCERTS certificate MC050062	U <sub>rs</sub>	mg/m <sup>3</sup>	3.2				
lack of fit	lof	% of value	2	maximum allowable	U <sub>lof</sub>	mg/m <sup>3</sup>	18.3				
maximum short term zero drift (ABS) [after drift correction]	dz	% of value	0	day of testing	U <sub>dz</sub>	mg/m <sup>3</sup>	0				
maximum short term span drift (ABS) [after drift correction]	ds	% of value	0	day of testing	U <sub>ds</sub>	mg/m <sup>3</sup>	0				
influence of sample gas flow	f	% of value	-0.1	MCERTS certificate MC050062	U <sub>f</sub>	mg/m <sup>3</sup>	-0.91				
influence of sample gas pressure	p	% of value	0	MCERTS certificate MC050062	U <sub>p</sub>	mg/m <sup>3</sup>	0				
influence of ambient temperature zero point ( / 35k)	tz	% of value	1.4	MCERTS certificate MC050062	U <sub>tz</sub>	mg/m <sup>3</sup>	0				
influence of ambient temperature span point ( / 35k)	ts	% of value	-0.57	MCERTS certificate MC050062	U <sub>ts</sub>	mg/m <sup>3</sup>	0				
influence of supply voltage ( / 60V)	v	% of value	-1	MCERTS certificate MC050062	U <sub>v</sub>	mg/m <sup>3</sup>	-6.1				
cross sensitivity at zero	iz	% of value	0	MCERTS certificate MC050062	U <sub>iz</sub>	mg/m <sup>3</sup>	0				
cross sensitivity at span	is	% of value	3.9	MCERTS certificate MC050062	U <sub>is</sub>	mg/m <sup>3</sup>	35.6				
maximum leak	L	% of value	0	day of testing	U <sub>L</sub>	mg/m <sup>3</sup>	0				
uncertainty associated with calibration gas	adj	% of value	0	span gas calibration certificate	U <sub>adj</sub>	mg/m <sup>3</sup>	0				
† This MU budget calculates the measurement uncertainty (MU) based upon the equipment used and the Standard followed. The reported MU is that specified in Table 4.7 (in Section 4.6.1) of EA LFTGN08 v2 2010, and is the "Assumed maximum value for total uncertainty to be applied when assessing compliance of emissions from [landfill gas] engines" which is 40% for Total VOCs.							combined MU with O <sub>2</sub> correction		mg/m <sup>3</sup>	51.6	
							expanded MU with O <sub>2</sub> correction (k = 1.96)		mg/m <sup>3</sup>	101	
							expanded MU 95% CI with O <sub>2</sub> correction (k = 1.96) as percentage of measured value		%	6.4	
							expanded MU 95% CI (k = 1.96) as percentage of measured value for mass emission		%	7	
							expanded MU with O <sub>2</sub> correction (k = 1.96) as percentage of ELV [allowable 15.5%]		%	10.1	

method and sampling deviations
Sampling was performed in full compliance with the Standard, technical procedure and regulatory requirements.

## Part 2: Supporting Information - Appendix 2: Oxides of Nitrogen (as NO<sub>2</sub>) | Run 1

### Results

reference conditions are: STP, dry, 5% O<sub>2</sub>

parameter	units	result ± MU (95% CI)	units	result ± MU (95% CI)
Oxides of Nitrogen (as NO <sub>2</sub> ) †	mg/m <sup>3</sup>	567 ± 170	g/hr	378 ± 113

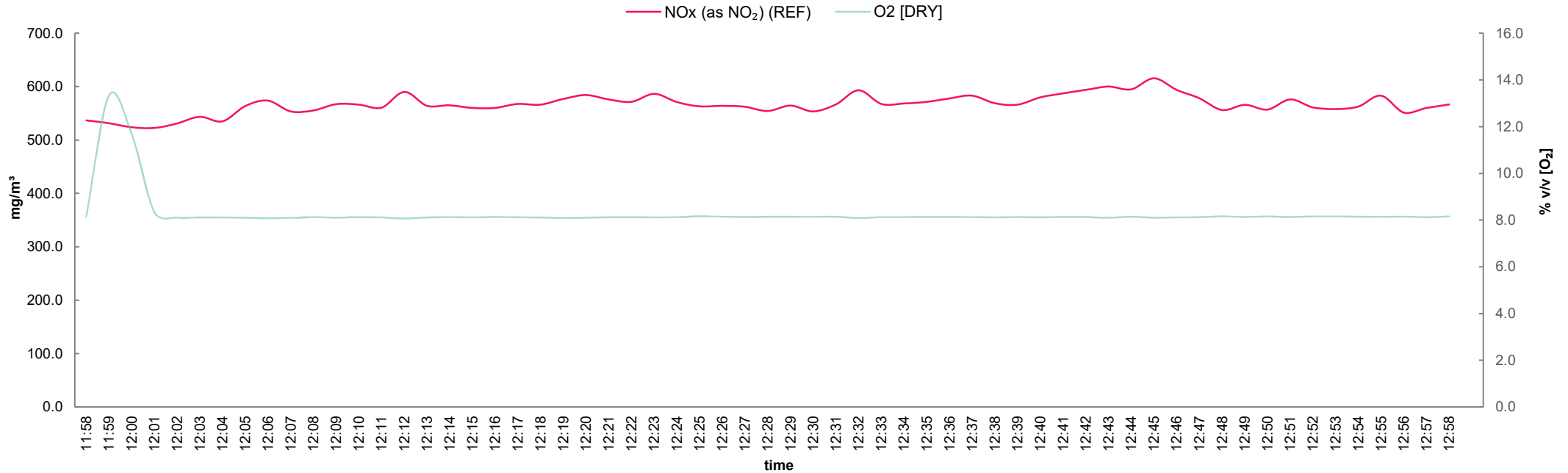
† LFTGN08 maximum value for total uncertainty (30% of measured value) applied to the results

### General Information

parameter	details
sampling start date & time	28/07/2022 11:58
sampling end date & time	28/07/2022 12:58
test time   mins	60
testing team	RH   SC
standard   technical procedure	EN 14792   TP-22a
analyser type	Horiba PG-350E
heated head & line temperature	180°C

parameter	details
probe material	Titanium
filter size, material & location	Filter Element PTFE   Within Heated Head
number sampling lines available	1
number sampling lines used	1
number sampling points ideal per line	1
number sampling points used per line	1
sampling point IDs	A1

### Plot of Emissions Over Time



## Part 2: Supporting Information - Appendix 2: Oxides of Nitrogen (as NO<sub>2</sub>) | Run 1

### Analyser Calibration Information with QA checks

where [A] = at analyser, [L] = down sampling line

CAL ID	pre-test calibration events							post-test calibration events			quality assurance						
	date & time	zero [A] [ppm]	span [A] [ppm]	zero [L] [ppm]	span [L] [ppm]	T <sub>90</sub> [s]	leak [%]	date & time	zero [A] [ppm]	span [A] [ppm]	zero drift [%]	span drift [%]	allowable [%]	temp [°C]			
1	28/07/22 11:24	0.00	413.70	0.20	412.00	55	0.4	P	28/07/22 13:24	1.40	416.00	0.3	P	0.2	P	±5	15.0

### Analyser Calibration Extended Information

CAL ID	performed by	drift corr. applied	log period [s]	CYL ID	CYL conc. [ppm]	CYL expiry	CYL MU [%]	zero gas type	span [CYL] gas type	span target [ppm]	range [ppm]	LOD [ppm]
1	RH	No	60	A-CYL-18	413.66	07/10/2023	1.2	Nitrogen 5.2	10l 400ppm NO   1600ppm CO   16% CO2 in Nitrogen	413.66	500	0.09

## Part 2: Supporting Information - Appendix 2: Oxides of Nitrogen (as NO<sub>2</sub>) | Run 1

### Measurement Uncertainty (MU) Calculations

general information	units	value
emission limit value (ELV) (REF)	mg/m <sup>3</sup>	500
measured concentration (REF)	mg/m <sup>3</sup>	567

MU budget			
parameter	units	min	max
ambient temp	°C	15.0	15.0
voltage	V	90.0	130.0

overall MU for O <sub>2</sub> correction
3.9%

MU factor O <sub>2</sub> correction
0.05

performance characteristics	MU budget input parameters				MU budget			result	
	symbol	units	value	source	symbol	units	value		
repeatability at zero	rz	% of value	0	MCERTS certificate MC130223	U <sub>rz</sub>	mg/m <sup>3</sup>	0	<p><i>This MU budget calculates the measurement uncertainty (MU) based upon the equipment used and the Standard followed. The reported MU is that specified in Table 4.7 (in Section 4.6.1) of EA LFTGN08 v2 2010, and is the "Assumed maximum value for total uncertainty to be applied when assessing compliance of emissions from [landfill gas] engines" which is 30% for Oxides of Nitrogen (as NO<sub>x</sub>).</i></p>	
repeatability at span	rs	% of value	0.1	MCERTS certificate MC130223	U <sub>rs</sub>	mg/m <sup>3</sup>	0.57		
lack of fit	lof	% of value	2	maximum allowable	U <sub>lof</sub>	mg/m <sup>3</sup>	6.5		
maximum short term zero drift (ABS) [after drift correction]	dz	% of value	0.34	day of testing	U <sub>dz</sub>	mg/m <sup>3</sup>	1.1		
maximum short term span drift (ABS) [after drift correction]	ds	% of value	0.22	day of testing	U <sub>ds</sub>	mg/m <sup>3</sup>	0.71		
influence of sample gas flow	f	% of value	0.1	MCERTS certificate MC130223	U <sub>f</sub>	mg/m <sup>3</sup>	0.33		
influence of sample gas pressure	p	% of value	0	MCERTS certificate MC130223	U <sub>p</sub>	mg/m <sup>3</sup>	0		
influence of ambient temperature zero point ( / 35k)	tz	% of value	0	MCERTS certificate MC130223	U <sub>tz</sub>	mg/m <sup>3</sup>	0		
influence of ambient temperature span point ( / 35k)	ts	% of value	1.8	MCERTS certificate MC130223	U <sub>ts</sub>	mg/m <sup>3</sup>	0		
influence of supply voltage ( / 60V)	v	% of value	0.4	MCERTS certificate MC130223	U <sub>v</sub>	mg/m <sup>3</sup>	0.87		
cross sensitivity at zero	iz	% of value	0.63	MCERTS certificate MC130223	U <sub>iz</sub>	mg/m <sup>3</sup>	2.1		
cross sensitivity at span	is	% of value	-0.52	MCERTS certificate MC130223	U <sub>is</sub>	mg/m <sup>3</sup>	-1.7		
maximum leak	L	% of value	0.41	day of testing	U <sub>L</sub>	mg/m <sup>3</sup>	1.3		
uncertainty associated with calibration gas	adj	% of value	1.2	span gas calibration certificate	U <sub>adj</sub>	mg/m <sup>3</sup>	3.5		
							combined MU with O <sub>2</sub> correction		14
							expanded MU with O <sub>2</sub> correction (k = 1.96)		27.4
							expanded MU 95% CI with O <sub>2</sub> correction (k = 1.96) as percentage of measured value	4.8	
							expanded MU 95% CI (k = 1.96) as percentage of measured value for mass emission	5.6	
							expanded MU with O <sub>2</sub> correction (k = 1.96) as percentage of ELV [allowable 10.7%]	5.5	

method and sampling deviations
Sampling was performed in full compliance with the Standard, technical procedure and regulatory requirements.

## Part 2: Supporting Information - Appendix 2: Carbon Monoxide | Run 1

### Results

reference conditions are: STP, dry, 5% O<sub>2</sub>

parameter	units	result ± MU (95% CI)	units	result ± MU (95% CI)
Carbon Monoxide †	mg/m <sup>3</sup>	877 ± 175	g/hr	584 ± 117

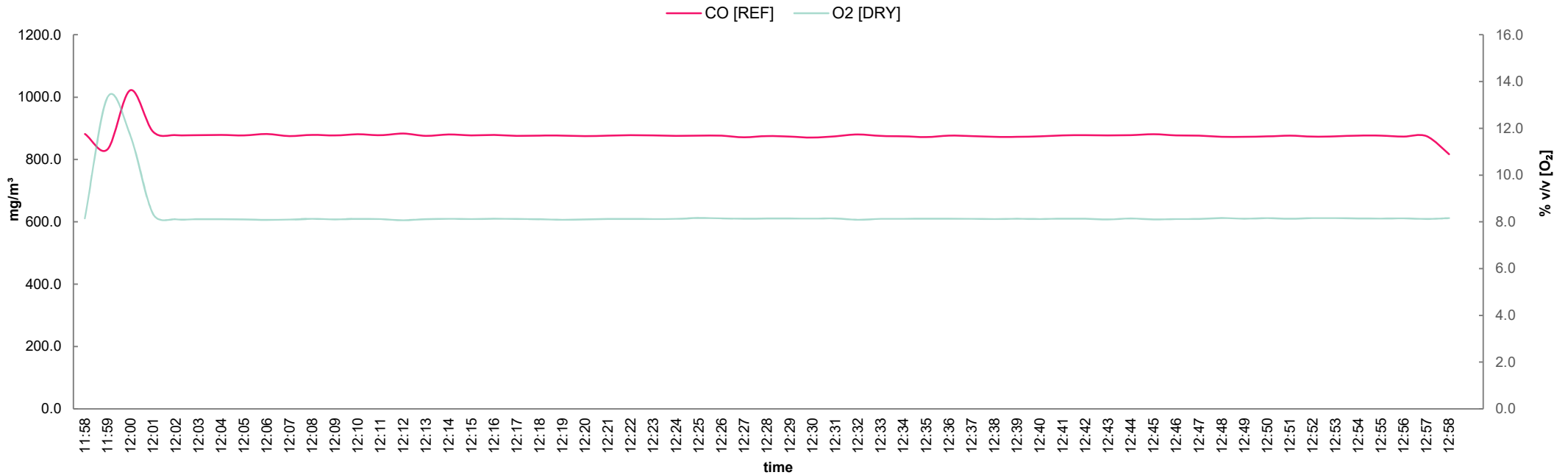
† LFTGN08 maximum value for total uncertainty (20% of measured value) applied to the results

### General Information

parameter	details
sampling start date & time	28/07/2022 11:58
sampling end date & time	28/07/2022 12:58
test time   mins	60
testing team	RH   SC
standard   technical procedure	EN 15058   TP-22b
analyser type	Horiba PG-350E
heated head & line temperature	180°C

parameter	details
probe material	Titanium
filter size, material & location	Filter Element PTFE   Within Heated Head
number sampling lines available	1
number sampling lines used	1
number sampling points ideal per line	1
number sampling points used per line	1
sampling point IDs	A1

### Plot of Emissions Over Time



## Part 2: Supporting Information - Appendix 2: Carbon Monoxide | Run 1

### Analyser Calibration Information with QA checks

where [A] = at analyser, [L] = down sampling line

CAL ID	pre-test calibration events							post-test calibration events			quality assurance			
	date & time	zero [A] [ppm]	span [A] [ppm]	zero [L] [ppm]	span [L] [ppm]	T <sub>90</sub> [s]	leak [%]	date & time	zero [A] [ppm]	span [A] [ppm]	zero drift [%]	span drift [%]	allowable [%]	temp [°C]
1	28/07/22 11:24	0.00	1641.00	1.00	1622.00	50	1.2 P	28/07/22 13:24	0.00	1635.00	0.0 P	-0.4 P	±5	15.0

### Analyser Calibration Extended Information

CAL ID	performed by	drift corr. applied	log period [s]	CYL ID	CYL conc. [ppm]	CYL expiry	CYL MU [%]	zero gas type	span [CYL] gas type	span target [ppm]	range [ppm]	LOD [ppm]
1	RH	No	60	A-CYL-18	1640.97	07/10/2023	1.1	Nitrogen 5.2	10l 400ppm NO   1600ppm CO   16% CO2 in Nitrogen	1640.97	2000	0.32

## Part 2: Supporting Information - Appendix 2: Carbon Monoxide | Run 1

### Measurement Uncertainty (MU) Calculations

general information	units	value
emission limit value (ELV) (REF)	mg/m <sup>3</sup>	1400
measured concentration (REF)	mg/m <sup>3</sup>	877

MU budget			
parameter	units	min	max
ambient temp	°C	15.0	15.0
voltage	V	90.0	130.0

overall MU for O <sub>2</sub> correction	3.9%
--	------

MU factor O <sub>2</sub> correction	0.05
-------------------------------------	------

performance characteristics	MU budget input parameters				MU budget			result			
	symbol	units	value	source	symbol	units	value				
repeatability at zero	rz	% of value	0.1	MCERTS certificate MC130223	U <sub>rz</sub>	mg/m <sup>3</sup>	0.88				
repeatability at span	rs	% of value	0.2	MCERTS certificate MC130223	U <sub>rs</sub>	mg/m <sup>3</sup>	1.8				
lack of fit	lof	% of value	2	maximum allowable	U <sub>lof</sub>	mg/m <sup>3</sup>	10.1				
maximum short term zero drift (ABS) [after drift correction]	dz	% of value	0	day of testing	U <sub>dz</sub>	mg/m <sup>3</sup>	0				
maximum short term span drift (ABS) [after drift correction]	ds	% of value	0.37	day of testing	U <sub>ds</sub>	mg/m <sup>3</sup>	1.9				
influence of sample gas flow	f	% of value	0.1	MCERTS certificate MC130223	U <sub>f</sub>	mg/m <sup>3</sup>	0.51				
influence of sample gas pressure	p	% of value	0	MCERTS certificate MC130223	U <sub>p</sub>	mg/m <sup>3</sup>	0				
influence of ambient temperature zero point ( / 35k)	tz	% of value	-0.2	MCERTS certificate MC130223	U <sub>tz</sub>	mg/m <sup>3</sup>	0				
influence of ambient temperature span point ( / 35k)	ts	% of value	2	MCERTS certificate MC130223	U <sub>ts</sub>	mg/m <sup>3</sup>	0				
influence of supply voltage ( / 60V)	v	% of value	0.5	MCERTS certificate MC130223	U <sub>v</sub>	mg/m <sup>3</sup>	1.7				
cross sensitivity at zero	iz	% of value	-0.48	MCERTS certificate MC130223	U <sub>iz</sub>	mg/m <sup>3</sup>	-2.4				
cross sensitivity at span	is	% of value	-0.87	MCERTS certificate MC130223	U <sub>is</sub>	mg/m <sup>3</sup>	-4.4				
maximum leak	L	% of value	1.2	day of testing	U <sub>L</sub>	mg/m <sup>3</sup>	5.9				
uncertainty associated with calibration gas	adj	% of value	1.1	span gas calibration certificate	U <sub>adj</sub>	mg/m <sup>3</sup>	4.9				
† This MU budget calculates the measurement uncertainty (MU) based upon the equipment used and the Standard followed. The reported MU is that specified in Table 4.7 (in Section 4.6.1) of EA LFTGN08 v2 2010, and is the "Assumed maximum value for total uncertainty to be applied when assessing compliance of emissions from [landfill gas] engines" which is 20% for Carbon Monoxide.							combined MU with O <sub>2</sub> correction		mg/m <sup>3</sup>	22.5	
							expanded MU with O <sub>2</sub> correction (k = 1.96)		mg/m <sup>3</sup>	44.1	
							expanded MU 95% CI with O <sub>2</sub> correction (k = 1.96) as percentage of measured value		%	5	
							expanded MU 95% CI (k = 1.96) as percentage of measured value for mass emission		%	5.8	
							expanded MU with O <sub>2</sub> correction (k = 1.96) as percentage of ELV [allowable 7.2%]		%	3.1	Pass

method and sampling deviations
Sampling was performed in full compliance with the Standard, technical procedure and regulatory requirements.

## Part 2: Supporting Information - Appendix 2: Oxygen | QA Concurrent Testing

### Results

parameter	units	result ± MU (95% CI)
Oxygen	% v/v	8.3 ± 0.22

### General Information

parameter	details
sampling start date & time	N/A - Concurrent Testing
sampling end date & time	N/A - Concurrent Testing
testing team	RH   SC

parameter	details
standard   technical procedure	EN 14789   TP-22d
analyser type	Horiba PG-350E

### Analyser Calibration Information with QA checks

where [A] = at analyser, [L] = down sampling line

CAL ID	pre-test calibration events								post-test calibration events			quality assurance					
	date & time	zero [A] [% v/v]	span [A] [% v/v]	zero [L] [% v/v]	span [L] [% v/v]	T <sub>90</sub> [s]	leak [%]		date & time	zero [A] [% v/v]	span [A] [% v/v]	zero drift [%]	span drift [%]	allowable [%]	temp [°C]		
1	28/07/22 11:24	0.00	20.66	0.19	20.59	50	0.3	P	28/07/22 13:24	0.07	20.63	0.2	P	-0.4	P	±5	15.0

### Analyser Calibration Extended Information

CAL ID	performed by	drift corr. applied	log period [s]	CYL ID	CYL conc. [% v/v]	CYL expiry	CYL MU [%]	zero gas type	span [CYL] gas type	span target [% v/v]	range [% v/v]	LOD [% v/v]
1	RH	No	60	A-CYL-47	20.66	01/12/2027	1.2	Nitrogen 5.2	10l Synthetic Air	20.66	25	0.03

## Part 2: Supporting Information - Appendix 2: Oxygen | QA Concurrent Testing

### Measurement Uncertainty (MU) Calculations

general information	units	value
measured concentration (dry)	% v/v	8.3

MU budget			
parameter	units	min	max
ambient temp	°C	15.0	15.0
voltage	V	90.0	130.0

performance characteristics	MU budget input parameters				MU budget		
	symbol	units	value	source	symbol	units	value
repeatability at zero	rz	% of value	0.02	MCERTS certificate MC130223	U <sub>rz</sub>	% v/v	0.0017
repeatability at span	rs	% of value	0.02	MCERTS certificate MC130223	U <sub>rs</sub>	% v/v	0.0017
lack of fit	lof	% of value	2	maximum allowable	U <sub>lof</sub>	% v/v	0.096
maximum short term zero drift (ABS) [after drift correction]	dz	% of value	0.24	day of testing	U <sub>dz</sub>	% v/v	0.012
maximum short term span drift (ABS) [after drift correction]	ds	% of value	0.39	day of testing	U <sub>ds</sub>	% v/v	0.018
influence of sample gas flow	f	% of value	-0.01	MCERTS certificate MC130223	U <sub>f</sub>	% v/v	-0.00048
influence of sample gas pressure	p	% of value	0	MCERTS certificate MC130223	U <sub>p</sub>	% v/v	0
influence of ambient temperature zero point ( / 35k)	tz	% of value	-0.4	MCERTS certificate MC130223	U <sub>tz</sub>	% v/v	0
influence of ambient temperature span point ( / 35k)	ts	% of value	-0.15	MCERTS certificate MC130223	U <sub>ts</sub>	% v/v	0
influence of supply voltage ( / 60V)	v	% of value	0.02	MCERTS certificate MC130223	U <sub>v</sub>	% v/v	0.00064
cross sensitivity at zero	iz	% of value	0	MCERTS certificate MC130223	U <sub>iz</sub>	% v/v	0
cross sensitivity at span	is	% of value	0	MCERTS certificate MC130223	U <sub>is</sub>	% v/v	0
maximum leak	L	% of value	0.34	day of testing	U <sub>L</sub>	% v/v	0.016
uncertainty associated with calibration gas	adj	% of value	1.2	span gas calibration certificate	U <sub>adj</sub>	% v/v	0.05
<i>combined MU</i>						% v/v	0.11
<i>expanded MU 95% CI (k = 1.96)</i>						% v/v	0.22
<i>expanded MU 95% CI (k = 1.96) as percentage of measured value</i>						%	2.6

method and sampling deviations
Sampling was performed in full compliance with the Standard, technical procedure and regulatory requirements.

## Part 2: Supporting Information - Appendix 2: Velocity & Flow Rate Traverse | Run 1

### Supporting Information

parameter	units	value
barometric pressure	kPa	101.8
average wet density	kg/m <sup>3</sup>	0.554
average stack static pressure	Pa	75.0
pitot tube coefficient, C <sub>p</sub>	-	0.832

NM = Not Measured

Line A

static pressure = 75 Pa

Pt	Depth   m	ΔP   Pa	Temp   °C	Vel   m/s
1	0.08	488.0	363.1	34.7

### General Information

parameter	details
traverse date	28/07/2022
traverse times   performed by	13:25 - 13:30   performed by: RH   SC
standard   technical procedure	EN 16911-1   TR 17078   TP-04a
device used	S-type Pitot with KIMO MP 210 (2500Pa module)

Limit of Detection (LOD) is 2.5 m/s for this device combination

### Quality Assurance

parameter	details
result of pitot stagnation test	Pass
result of pitot leak check (pre)	Pass
result of pitot leak check (post)	Pass
water droplets present	No

## Part 2: Supporting Information - Appendix 2: Velocity & Flow Rate Traverse | Run 1

### Measurement Uncertainty (MU) Calculations

parameter	units	value
standard uncertainty on the coefficient of the pitot tube	-	0.0015
standard uncertainty associated with the mean local dynamic pressures	Pa	7.7
standard uncertainty associated with the molar mass of the gas	-	0.000057
standard uncertainty associated with the temperature	K	3.2
standard uncertainty associated with the absolute pressure in the duct	Pa	176
standard uncertainty associated with the density of the gas effluent	kg/m <sup>3</sup>	0.0032
standard uncertainty associated with the local velocities	m/s	0.3
standard uncertainty associated with the mean velocity	m/s	0.29

parameter	units	value
standard uncertainty associated with the mean velocity (95% CI)	m/s	0.58
standard uncertainty associated with the mean velocity (95% CI), relative	%	1.7
standard uncertainty associated with the volume flow rate @ actual (95% CI)	m <sup>3</sup> /hr	121
standard uncertainty associated with the volume flow rate @ actual (95% CI), relative	%	4.8
standard uncertainty associated with the volume flow rate @ ref 1 (95% CI)	m <sup>3</sup> /hr	36.8
standard uncertainty associated with the volume flow rate @ ref 1 (95% CI), relative	%	4.8

#### method and sampling deviations

Sampling was performed in full compliance with the Standard, technical procedure and regulatory requirements.