



ARM Group LLC

Engineers and Scientists

November 14th, 2023

Ms. Niti Blackwell
Howard County Department of Public Works
Bureau of Environmental Services
9801 Broken Land Parkway
Columbia, MD 21046

Re: Landfill Fuel Gas Analysis
Alpha Ridge Landfill
Howard County, Maryland
ARM Project 23011496

Dear Ms. Blackwell,

ARM Group LLC (ARM) is pleased to submit this letter report to the Howard County Department of Public Works, Bureau of Environmental Services (the County) for the analysis of one sample of landfill gas (LFG) collected at the Alpha Ridge Landfill (the Site) in Marriottsville, MD.

On October 30th, 2023, an ARM geologist mobilized to the Site near the LFG flare. The geologist connected a quick-connect adaptor and a short piece of silicone tubing to a sample tap on the LFG blower line. The silicone tubing was then connected to a one-liter Tedlar bag, the valve on the bag was opened, and the bag was filled with LFG to approximately 90% capacity to prevent rupture of the bag during shipping. The LFG sample was shipped to Analytical Solution, Inc. for the following laboratory analyses:

- Gas Component Analysis, including Hydrogen and Carbon Monoxide
- Compound Speciation – Siloxanes
- Compound Speciation – Sulfur Components

The laboratory results from this sampling event were compared to the laboratory results from the previous LFG sample collected on October 17th, 2022. **Tables 1-4** (attached) highlight major differences between the two most recent samples and display the results from previous samples collected from 2013 to 2021. In general, the 2023 sample contained higher detections of nitrogen, oxygen, siloxanes, and total sulfur, but lower detections of methane and carbon dioxide as compared to the 2022 sample. Hydrogen and carbon monoxide have been included as analysis parameters since 2022. The full laboratory report is included as **Attachment 1**.

If you have questions regarding any information covered in this document, please feel free to contact ARM Group LLC at (410)-290-7775.

Respectfully Submitted,
ARM Group LLC



Lauren Parker, G.I.T.
Staff Geologist

Q.A. Review performed by Eric Magdar, P.G.

Attachments:

- Table 1** – Sample Information
- Table 2** – Gas Component Analysis Comparison
- Table 3** – Siloxanes Speciation Comparison
- Table 4** – Sulfur Speciation Comparison
- Attachment 1** - Laboratory Results



TABLES

Table 1 — Sample Information

Sample Date	<u>12/3/2013</u>	<u>5/29/2015</u>	<u>10/6/2016</u>	<u>11/16/2017</u>	<u>11/14/2018</u>	<u>11/21/2019</u>	<u>11/5/2020</u>	<u>9/3/2021</u>	<u>10/17/2022</u>	<u>10/30/2023</u>
Sample Name	LFG, ARL-1	AR-LFG1	AR-LFG Blower	AR-LFG blower	ARLF Fuel Gas	ARLF Fuel Gas	ARLF Fuel Gas	ARLF Fuel Gas	ARLF Fuel Gas	ARLF Fuel Gas
Sample Time	1345	815	815	805	958	1406	915	900	1410	1020
Lab Sample ID	N1205a01	Q0602c01	R1007b01	S1120a01	T1119b01	V1122a01	W1110b01	X0909b01	Y1018a01	Z1031a01
Report Date	12/20/2013	6/2/2015	10/27/2016	11/30/2017	12/28/2018	12/9/2019	11/24/2020	9/24/2021	10/26/2022	11/9/2023

Table 2 — Gas Component Analysis Comparison

Parameter	Conc. Unit	<u>Concentration</u> <u>12/3/2013</u>	<u>Concentration</u> <u>5/29/2015</u>	<u>Concentration</u> <u>10/6/2016</u>	<u>Concentration</u> <u>11/16/2017</u>	<u>Concentration</u> <u>11/14/2018</u>	<u>Concentration</u> <u>11/21/2019</u>	<u>Concentration</u> <u>11/5/2020</u>	<u>Concentration</u> <u>9/3/2021</u>	<u>Concentration</u> <u>10/17/2022</u>	<u>Concentration</u> <u>10/30/2023</u>
Hydrogen	%	--	--	--	--	--	--	--	--	<0.01	<0.01
Methane	%	51.8	51.7	45.5	47.7	45.8	42.2	43.2	33.8	54.7	48.8
Carbon Monoxide	%	--	--	--	--	--	--	--	--	<0.01	<0.01
Carbon Dioxide	%	37.3	32	21.4	33	31.4	29.6	30.5	26.21	36.1	30.6
Nitrogen	%	10.39	14.59	20.5	17.5	20.42	25	25.2	35.8	8.69	16.57
Oxygen	%	0.51	1.73	2.69	1.77	2.29	3.25	1.08	4.09	0.49	4.01
GHV, dry (14.73 psi)	Btu/scf	526	524	461	484	465	428	439	343	556	495
NHV, dry (14.73 psi)	Btu/scf	474	472	415	436	419	385	395	309	500	446
Relative density		0.962	0.935	0.958	0.957	0.956	0.963	0.96	0.979	0.943	0.942

Larger values of two most recent events highlighted in red

Table 3 — Siloxanes Speciation Comparison

Parameter	Conc. Unit	Conc.	Conc.	Conc.	Conc.	Conc.	Conc.	Conc.	Conc.	Conc.	Conc.
		12/3/2013	5/29/2015	10/6/2016	11/16/2017	11/14/2018	11/21/2019	11/5/2020	9/3/2021	10/17/2022	10/30/2023
Tetramethyl Silane	ppmv as Si	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Trimethyl Silanol	ppmv as Si	0.116	<0.02	0.149	0.038	0.058	0.092	0.059	<0.02	<0.02	<0.02
Hexamethyldisiloxane (L2)	ppmv as Si	<0.02	<0.02	<0.02	<0.02	<0.02	0.044	0.008	<0.02	<0.02	<0.02
Hexamethylcyclotrisiloxane (D3)	ppmv as Si	0.087	0.249	0.095	0.055	0.018	0.48	0.011	<0.02	<0.02	<0.02
Octamethyltrisiloxane (L3)	ppmv as Si	<0.02	<0.02	<0.02	<0.02	<0.02	0.086	0.022	<0.02	<0.02	<0.02
Octamethylcyclotetrasiloxane (D4)	ppmv as Si	0.97	0.65	0.62	0.71	0.46	0.75	0.94	0.59	0.49	0.59
Decamethyltetrasiloxane (L4)	ppmv as Si	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Decamethylcyclopentasiloxane (D5)	ppmv as Si	0.35	0.186	0.284	0.31	0.32	0.34	1.2	0.103	0.122	0.166
Dodecamethylpentasiloxane (L5)	ppmv as Si	<0.02	<0.02	<0.02	<0.02	<0.02	0.071	<0.02	<0.02	<0.02	<0.02
Dodecamethylcyclohexasiloxane (D6)	ppmv as Si	<0.02	<0.02	0.21	0.49	0.149	0.96	0.096	0.255	0.02	0.11
Others. as L2	ppmv as Si	0.11	<0.01	0.02	0.02	0.02	0.04	0.26	0.05	0.05	0.03
Total	ppmv as Si	1.63	1.08	1.38	1.62	1.03	2.86	2.6	1.00	0.68	0.90
Tetramethyl Silane	ppmv	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Trimethyl Silanol	ppmv	0.116	<0.02	0.149	0.038	0.058	0.092	0.059	<0.02	<0.02	<0.02
Hexamethyldisiloxane (L2)	ppmv	<0.01	<0.01	<0.01	<0.01	<0.01	0.022	0.004	<0.01	<0.01	<0.01
Hexamethylcyclotrisiloxane (D3)	ppmv	0.029	0.083	0.032	0.018	0.006	0.161	0.004	<0.007	<0.007	<0.007
Octamethyltrisiloxane (L3)	ppmv	<0.01	<0.01	<0.01	<0.01	<0.01	0.029	0.007	<0.007	<0.007	<0.007
Octamethylcyclotetrasiloxane (D4)	ppmv	0.242	0.162	0.155	0.178	0.115	0.187	0.236	0.147	0.123	0.147
Decamethyltetrasiloxane (L4)	ppmv	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Decamethylcyclopentasiloxane (D5)	ppmv	0.071	0.037	0.057	0.062	0.065	0.068	0.241	0.021	0.024	0.033
Dodecamethylpentasiloxane (L5)	ppmv	<0.005	<0.004	<0.004	<0.004	<0.004	0.014	<0.02	<0.004	<0.004	<0.004
Dodecamethylcyclohexasiloxane (D6)	ppmv	<0.005	<0.004	0.035	0.081	0.025	0.16	0.016	0.043	0.003	0.018
Others. as L2	ppmv	0.055	<0.005	0.01	0.01	0.01	0.02	0.13	0.025	0.025	0.015
Tetramethyl Silane	mg Si/M3	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Trimethyl Silanol	mg Si/M3	0.138	<0.03	0.176	0.045	0.069	0.109	0.07	<0.03	<0.03	<0.03
Hexamethyldisiloxane (L2)	mg Si/M3	<0.03	<0.03	<0.03	<0.03	<0.03	0.052	0.01	<0.03	<0.03	<0.03
Hexamethylcyclotrisiloxane (D3)	mg Si/M3	0.103	0.296	0.113	0.065	0.022	0.57	0.013	<0.03	<0.03	<0.03
Octamethyltrisiloxane (L3)	mg Si/M3	<0.03	<0.03	<0.03	<0.03	<0.03	0.102	0.026	<0.03	<0.03	<0.03
Octamethylcyclotetrasiloxane (D4)	mg Si/M3	1.15	0.77	0.73	0.84	0.55	0.89	1.12	0.7	0.58	0.7
Decamethyltetrasiloxane (L4)	mg Si/M3	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Decamethylcyclopentasiloxane (D5)	mg Si/M3	0.42	0.22	0.337	0.37	0.38	0.4	1.43	0.122	0.145	0.197
Dodecamethylpentasiloxane (L5)	mg Si/M3	<0.03	<0.03	<0.03	<0.03	<0.03	0.084	<0.03	<0.03	<0.03	<0.03
Dodecamethylcyclohexasiloxane (D6)	mg Si/M3	<0.03	<0.03	0.249	0.58	0.176	1.14	0.113	0.303	0.024	0.13
Others. as L2	mg Si/M3	0.13	<0.02	0.02	0.03	0.02	0.05	0.3	0.06	0.05	0.04
Total	mg Si/M3	1.94	1.28	1.63	1.93	1.22	3.4	3.08	1.18	0.80	1.07

Conc. = Concentration

Larger values of two most recent events highlighted in red

Table 4 — Sulfur Speciation Analysis

Parameter	Conc. Units	Concentration 12/3/2013	Concentration 5/29/2015	Concentration 10/6/2016	Concentration 11/16/2017	Concentration 11/14/2018	Concentration 11/21/2019	Concentration 11/5/2020	Concentration 9/3/2021	Concentration 10/17/2022	Concentration 10/30/2023
Hydrogen Sulfide	ppmv	0.42	11.6	15.82	14.48	5.11	6.53	12.6	3.96	17.8	21.06
Carbonyl Sulfide	ppmv	0.12	<0.10	6.56	0.2	0.98	2.34	0.7	0.7	0.36	0.99
Methyl Mercaptan	ppmv	<0.05	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	0.11	<0.10
Ethyl Mercaptan	ppmv	<0.05	<0.10	<0.10	<0.10	<0.10	<0.10	0.17	<0.10	<0.10	<0.10
Dimethyl Sulfide	ppmv	<0.05	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Carbon Disulfide	ppmv	<0.05	<0.10	0.06	0.38	<0.10	<0.10	0.18	<0.10	0.14	<0.10
i-Propyl Mercaptan	ppmv	<0.05	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
t-Butyl Mercaptan	ppmv	0.06	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
n-Propyl Mercaptan	ppmv	<0.05	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Thiophene/Sec-Butyl mercaptan	ppmv	--	<0.10	<0.10	0.19	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Ethylmethyl sulfide	ppmv	0.05	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	0.13	<0.10
Thiophene	ppmv	0.06	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Diethyl Sulfide	ppmv	<0.05	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Dimethyl Disulfide	ppmv	<0.03	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Ethyl Methyl Disulfide	ppmv	<0.03	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Diethyl Disulfide	ppmv	<0.05	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Methyl Thiophenes	ppmv	--	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Others (as S)	ppmv	1.15	2.87	2.97	3.83	0.31	1.35	0.92	4.84	2.75	0.41
Total S	ppmv	1.86	14.6	25.5	19.5	6.39	10.22	14.8	9.77	21.4	22.4
Total S	mg/m3	2.52	19.7	34.5	26.4	8.65	13.84	20	13.22	29	30.4

Larger values of two most recent events highlighted in red

**ATTACHMENT 1 –
LABORATORY RESULTS**

ANALYTICAL SOLUTION, INC. (AnSol)

11/09/23

Analytical Report

Sample log # : Z1031a

Purchase Order #:	<i>COC-request</i>	Customer Project:	<i>ARLF</i>
Company :	<i>ARM Group</i>	Requester :	<i>Stewart Kabis</i>
Address :	<i>9175 Guilford Rd. Suite 310 Columbia, MD 21046</i>	Phone:	<i>410-290-7775</i>
		Fax:	<i>410-290-7776</i>
Sample Description :	<i>LFG</i>	Received Date :	<i>10/31/23</i>
Number of Samples :	<i>1</i>	Total Report Page:	<i>4</i>

Note: This report is submitted to the requester through E-mail only. Please let us know if your need this document security signed, or a hard copy report by mail or fax.

Results:

All results are attached in following pages.

The calculation is based on standard conditions at 60°F and 14.73 psia, where applied

Submitted by: Sherman S. Chao, Ph.D.

Tel: (630) 230-9378, Fax: (630) 230-9376

Disclaimer:

Neither AnSol nor any person acting on behalf of AnSol assumes any liability with respect to the use of, or for damages resulting from the use of, any information presented in this report.

Analytical Solution, Inc., 7320 S. Madison, Unit 500, Willowbrook, Illinois 60527

GAS COMPONENT ANALYSIS

Sample ID:	Conc. Unit	Z1031a01
	Description:	ARLF Fuel Gas 2023, 10/30/23, 1020
Hydrogen	%	<0.01
Methane	%	48.8
Carbon monoxide	%	<0.01
Carbon dioxide	%	30.6
Nitrogen	%	16.57
Oxygen	%	4.01
GHV, dry (14.73 psi) *	Btu/scf	495
NHV, dry (14.73 psi) *	Btu/scf	446
Relative density *		0.942

* Calculation based on major components listed.

Note: ASTM D-1945. All major component concentrations were reported as a moisture, H₂S and C₂ plus free basis and were normalized to 100%. Oxygen and Argon cannot be separated; therefore, the oxygen result includes a small amount of Argon. Some results may be reported with additional significance for reference. ND=Not Determined

Compound Speciation – Siloxanes

	Z1031a01		
Organic Silicon (siloxanes)	ARLF Fuel Gas 2023, 10/30/23, 1020		
	ppmv as Si	ppmv	mg Si/M ³
Tetramethyl silane	<0.02	<0.02	<0.03
Trimethyl silanol	<0.02	<0.02	<0.03
Hexamethyldisiloxane (L2)	<0.02	<0.01	<0.03
Hexamethylcyclotrisiloxane (D3)	<0.02	<0.007	<0.03
Octamethyltrisiloxane (L3)	<0.02	<0.007	<0.03
Octamethylcyclotetrasiloxane (D4)	0.59	0.147	0.70
Decamethyltetrasiloxane (L4)	<0.02	<0.005	<0.03
Decamethylcyclopentasiloxane (D5)	0.166	0.033	0.197
Dodecamethylpentasiloxane (L5)	<0.02	<0.004	<0.03
Dodecamethylcyclohexasiloxane (D6)	0.110	0.018	0.130
Others. as L2	0.03	0.015	0.04
Total:	0.90		1.07

Note: Some results may be reported with additional significance for reference. Others may include traces (BDL) of 10 target compounds. Silicone-based lubricant on the valve stem of Tedlar bag or in the sampling line often contributes a low but significant background level of siloxanes (D5 & D6, mainly).

Compound Speciation – Sulfur Components

	Z1031a01
Sulfur Compounds, ppmv	ARLF Fuel Gas 2023, 10/30/23, 1020
Hydrogen sulfide	21.06
Carbonyl sulfide	0.99
Methyl mercaptan	<0.10
Ethyl mercaptan	<0.10
Dimethyl sulfide	<0.10
Carbon disulfide *	<0.10
i-Propyl mercaptan	<0.10
t-Butyl mercaptan	<0.10
n-Propyl mercaptan	<0.10
Ethylmethyl sulfide	<0.10
Sec-Butyl mercaptan	<0.10
Thiophene	<0.10
Diethyl sulfide	<0.10
Dimethyl disulfide *	<0.10
Ethyl methyl disulfide *	<0.10
Diethyl disulfide *	<0.10
Methyl thiophenes	<0.10
Others (as S)	0.41
Total S: (ppmv)	22.4
(mg/M3)	30.4

Note: ASTM method. Some results were reported with additional significance for reference. The normal detection limit of each sulfur compound is .0.1 ppmv S.

* 1.0 ppmv as sulfur = 0.50 ppmv sulfur compound