NC STATE UNIVERSITY

Memo

To: Dylan Gehrken, Founder and President Grease Cycle®

From: Joel Ducoste, Ph.D., BCEEM, Amanda Karam, M.S., Doctoral Candidate

Date: 04/7/2021

Re: Assessing the Effluent Quality of Grease Interceptors: Evaluation of On-site Processing Maintenance Strategy

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Executive summary

The contents of this memo provide an overview of the methods and results from a small-scale study that investigated Grease Cycle's® on-site processing method on a 30-day frequency for grease interceptor maintenance at food service establishments (FSE) as compared to traditional full evacuation methods.

The overall findings of this study are summarized below:

- The measured oil and grease concentration, using *EPA Method 1664, Revision B: n-Hexane Extractable Material (HEM; Oil and Grease),* in the outlet wastewater of grease interceptors with recycled greywater, averaged across 30-day cycles, was no different from the outlet water of interceptors which had full pump-out of waste material.
- On-site processing may affect the FSE wastewater discharge pH for certain food service establishments. While pH values were not outside of values typical of FSE grease interceptor effluent discharge, three of the six sites studied here displayed slightly elevated pH values associated with on-site treatment.

1. Introduction:

Externally located grease interceptors (GIs) are the primary mitigation strategies to limit the release of fats, oils, and grease (FOG) from food service establishments (FSEs) into the sanitary

sewer system. Gravity drives the separation of FOG and food particles to 'trap' these contents in the GI before kitchen effluent wastewater enters the sewage system. These GIs must be serviced every few weeks to months to remove the accumulated waste products and typically involves the removal of all liquid and solid contents with a vacuum truck.

The goal of this study was to investigate Grease Cycle's® on-site processing (OP) method to service GIs using a vacuum separation truck technology that has a filtration unit to remove FOG and food solids and subsequently return the filtered greywater back into the GI (*OMEGA SG™, Septic & Grease*, see Supplemental Information, SI 4.1). The evaluation of this OP approach has been performed by measuring the FOG concentration in the effluent of GIs at six different restaurants during two phases in 2020 using *EPA Method 1664, Revision B: n-Hexane Extractable Material (HEM; Oil and Grease)* (EPA Method 1664B).

During this study, FSEs were selected and serviced by Grease Cycle® with the OP method and the traditional full evacuation pump-out (FP) approach where all the contents of the GI were completely evacuated and transported off-site for further treatment. A detailed description of the experimental methods, test schedule, and location of treatments are provided in Section 4 of this report.

2. Results:

Figures 1 and 2 provide an overview of the FOG data and the pH data distribution, respectively, collected across sites for both phases of this study using boxplots, which show the median value, interquartile range, minimum and maximum values including outliers. The figures show the GI effluent properties for each service period monitored between January 2020-March 2020, Phase 1 (P1) and September 2020-January 2021, Phase 2 (P2).

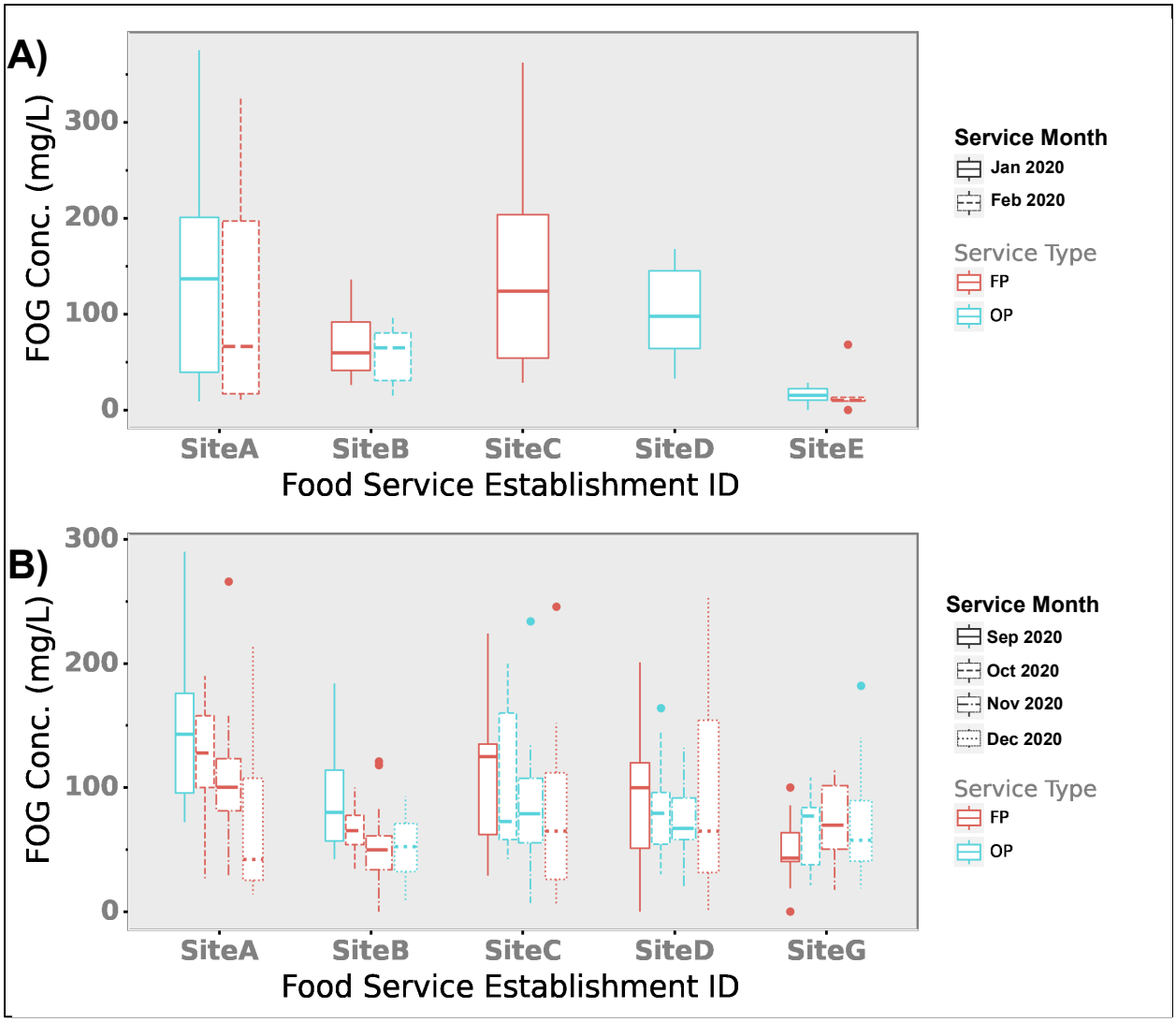


Figure 1. Boxplots showing the FOG concentration of GI outlet water after being serviced by either on-site processing (OP, blue) or by a full evacuation pump-out (FP, red) during Phase 1 (A) and Phase 2 (B) of this study. Each boxplot shows data collected over 30-day service periods, except for boxplots for Site C and Site D in Phase 1, in which data was collected over a 60-day cycle. For more details regarding site and services description see Table 2-4 in Section 4. *Note*: site identifiers are consistent across both phases and reflect the same FSE.

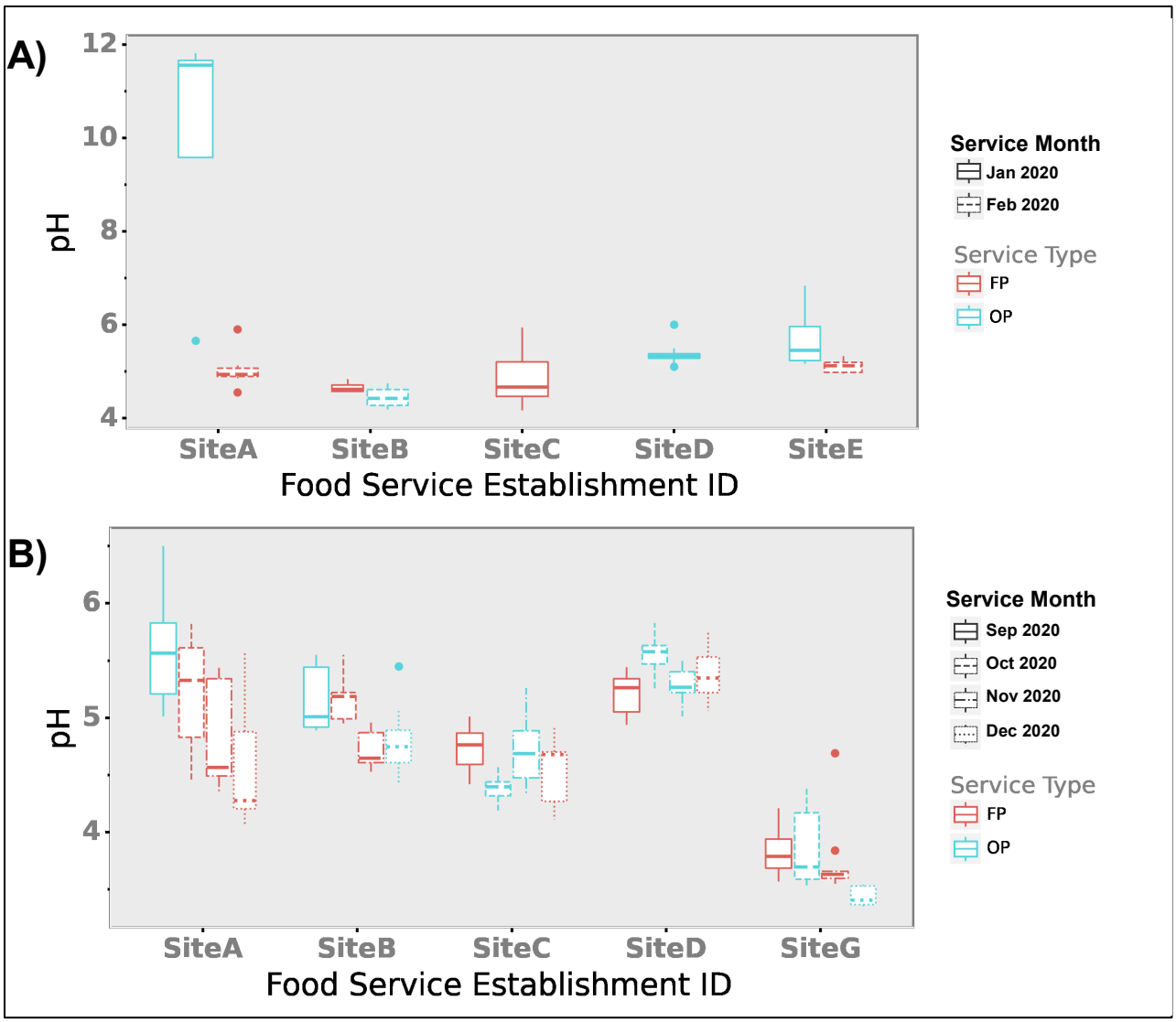


Figure 2. Boxplots showing the pH of GI outlet water after being serviced by either on-site processing (OP, blue) or by a full evacuation pump-out (FP, red) during Phase 1 (A) and Phase 2 (B) of this study. Each boxplot shows data collected over 30-day service periods, except for boxplots for Site C and Site D in Phase 1, in which data was collected over a 60-day cycle. For more details regarding site and services description see Table 2-4 in Section 4. *Note*: site identifiers are consistent across both phases and reflect the same FSE.

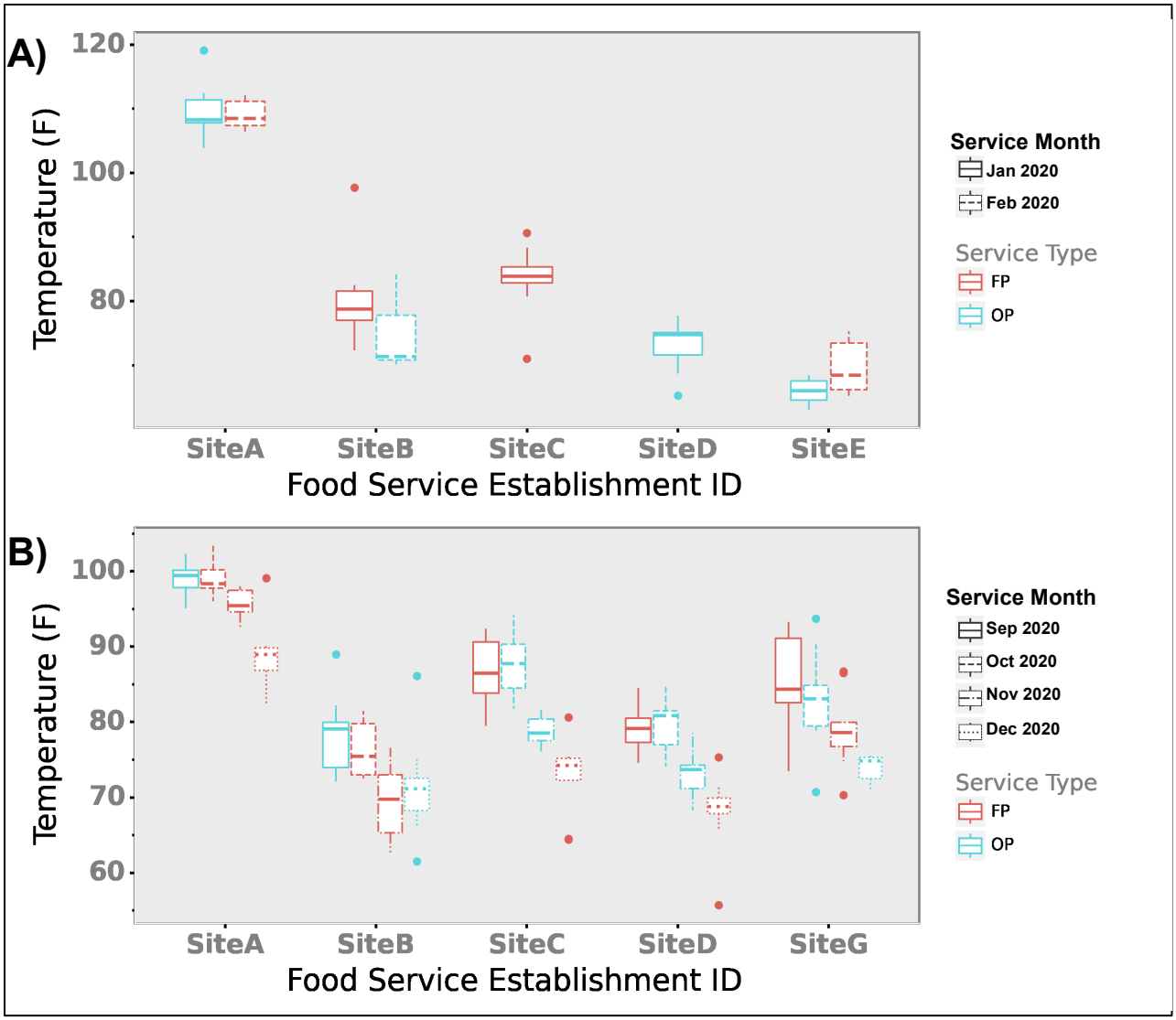


Figure 3. Boxplots showing the temperature of GI outlet water after being serviced by either on-site processing (OP, blue) or by a full evacuation pump-out (FP, red) during Phase 1 (A) and Phase 2 (B) of this study. Each boxplot shows data collected over 30-day service periods, except for boxplots for Site C and Site D in Phase 1, in which data was collected over a 60-day cycle. For more details regarding site and services description see Table 2-4 in Section 4. *Note*: site identifiers are consistent across both phases and reflect the same FSE.

Table 1 summarizes the overall average values of the FOG, temperature, and pH of the six GI testing sites for this study. The data in Phase 1 and Phase 2 testing periods are presented separately due to the potential differences in FSE effluent wastewater conditions before and during COVID-19. No major differences were observed for the measured effluent FOG concentration between the two treatment types at the sites tested during either phase (Figure 1). As shown in Figure 2, elevated pH levels were observed for Site A and Site E during Phase 1. The very high pH in Site A during the first part of Phase 1 testing was not observed at other times during the study and may be specific to a unique FSE discharge that occurred at that particular time of sampling and may

not be due to the GI maintenance treatment strategy. Site D had a statistically significant yet marginally higher pH difference over the course of Phase 2. Site A showed higher pH for on-site in Phase 2, albeit there was only one round of on-site processing due to scheduling and thus no statistical tests were run due to uneven sample size.

Site A's uneven service treatment, *i.e.*, one OP service followed by three FP, did however, give insight to potential seasonal factors as the FOG concentration and pH displayed a slight decrease with time over the Phase 2 testing period as shown in Figures 1B and 2B. Variations in the FOG concentration and pH may be due to several factors including changes in FSE kitchen practices, patron visitation behavior, and seasonal temperature variations (Figure 3). All variations in the FOG concentration were generally below 200 ppm and, with the exception of Site A (P1 September) and Site G (P2), the pH was within the standard discharge limits into sewer systems. All data associated with this study is available upon request.

Table 1. Overview of measured site parameters showing the mean, standard deviation (std), and number of samples. Phase 1, occurred in January-March 2020. Phase 2 occurred in September 2020 –January 2021.

			FOG (mg/L)			***Temperature (F)***			***pH***		
FSE ID	**Phase**	**Service Type**	**mean**	**std**	**count**	**mean**	**std**	**count**	**mean**	**std**	**count**
Site A	Phase1	FP	119	135	7	109	2	7	5.04	0.42	7
		OP	150	129	8	110	5	6	10.05	2.62	5
	Phase2	FP	99	59	40	95	5	26	4.88	0.57	25
		OP	152	72	10	99	2	10	5.59	0.46	10
Site B	Phase1	FP	68	37	8	81	9	6	4.66	0.13	4
		OP	57	33	7	75	6	7	4.46	0.23	7
	Phase2	FP	61	25	28	73	6	18	4.95	0.29	18
		OP	66	39	25	75	7	19	4.99	0.34	18
Site C	Phase1	FP	151	115	14	84	5	12	4.88	0.57	11
	Phase2	FP	92	63	24	80	9	19	4.64	0.26	19
		OP	91	57	27	83	5	19	4.55	0.27	19
Site D	Phase1	OP	102	45	14	73	4	11	5.37	0.23	11
	Phase2	FP	101	67	22	74	7	18	5.28	0.22	17
		OP	77	35	27	76	5	18	5.43	0.23	18
Site E	Phase1	FP	19	25	6	70	4	6	5.11	0.15	6
		OP	16	10	8	66	2	6	5.73	0.77	4
Site G	Phase2	FP	63	32	30	82	6	20	3.78	0.27	20
		OP	68	40	24	79	7	17	3.66	0.33	18

Quality Control and Method Analysis:

Table 2 displays an overview of the routine quality control (QC) results for matrix spiking samples at performed by Pace Analytical. These QC measures are required as part of EPA Method 1664B. For each batch of samples analyzed during Phase 2, one of the five sites were randomly selected for matrix spiking as part of quality control.

Table 2. Overview of quality control data for the various batches of data analyzed by Pace Lab over the Phase 2 part of this study. Bold-faced values highlight the spiked samples that passed quality control, i.e., 80-120% recovery after spiking a sample.

Date	FSE ID	Treatment type	Days after service	Background conc. (mg/L)	Conc. of sample spiked with 40 mg/L (mg/L)	% Recovery Matrix Spike	Passed QC for matrix spike?
9/24/2020	Site A	OP	2	176	270	235%	No
9/25/2020	**Site C**	**FP**	**3**	**132**	**174**	**105%**	**Yes**
9/26/2020	Site G	FP	4	43.1	65.2	55%	No
10/1/2020	Site D	FP	9	149	102	-118%	No
10/2/2020	**Site B**	**OP**	**10**	**64**	**106**	**105%**	**Yes**
10/8/2020	Site C	FP	16	224	75	-373%	No
10/9/2020	Site A	OP	17	132	205	183%	No
10/15/2020	Site B	OP	23	114	113	-3%	No
10/16/2020	Site G	FP	24	43.2	51	20%	No
10/17/2020	Site D	FP	25	63.1	289	565%	No
10/22/2020	**Site C**	**OP**	**2**	**57.9**	**91.9**	**85%**	**Yes**
10/23/2020	**Site A**	**FP**	**3**	**149**	**190**	**103%**	**Yes**
10/23/2020	Site B	FP	3	47.3	48.9	4%	No
10/24/2020	Site G	OP	9	92.3	92.5	1%	No
10/29/2020	Site D	OP	9	146	10.7	-338%	No
10/30/2020	Site B	FP	10	71.2	178	267%	No
11/5/2020	Site G	OP	16	76.2	34	-106%	No
11/6/2020	Site C	OP	17	42.3	39.4	-7%	No
11/13/2020	Site A	FP	24	190	72.5	-294%	No
11/14/2020	Site D	OP	25	78.9	84.2	13%	No
11/18/2020	Site C	OP	1	23.5	23.3	0%	No
11/20/2020	Site B	FP	5	47.6*	67	49%	No
11/25/2020	Site D	OP	8	126*	118	-20%	No
12/3/2020	Site G	FP	16	54.1*	118	160%	No
12/10/2020	Site D	OP	23	93.4*	160	167%	No
12/12/2020	Site A	FP	25	83.6*	76.6	-17%	No
12/17/2020	**Site C**	**FP**	**2**	**10.5***	**44.8**	**86%**	**Yes**
12/19/2020	**Site B**	**OP**	**4**	**41.1***	**79.6**	**96%**	**Yes**
12/23/2020	Site D	FP	8	32.5	35.7	8%	No
12/30/2020	**Site G**	**OP**	**15**	**182**	**215**	**83%**	**Yes**
12/31/2020	Site A	FP	23	111	211	250%	No
1/8/2021	Site B	OP	24	64*	112	120%	No
1/9/2021	Site A	FP	25	153	156	8%	No

** Background concentration averaged from n = 2 technical replicate samples. All other background concentrations based on only one sample.*

Matrix spiking was performed by adding 40 mg/L of spiking solution (equal parts of hexadecane/stearic acid) to excess sample volume. The precision and recovery of oil and grease in the matrix solution was determined by comparing the measured FOG concentration of this spiked sample to the background concentration. QC failed 27 of the 33 batches tested. As shown in Figure 5, there does not seem to be any clear pattern in the direction of interferences or clear trends associated with treatment type, site, month, or time after service given the QC data collected during this study.

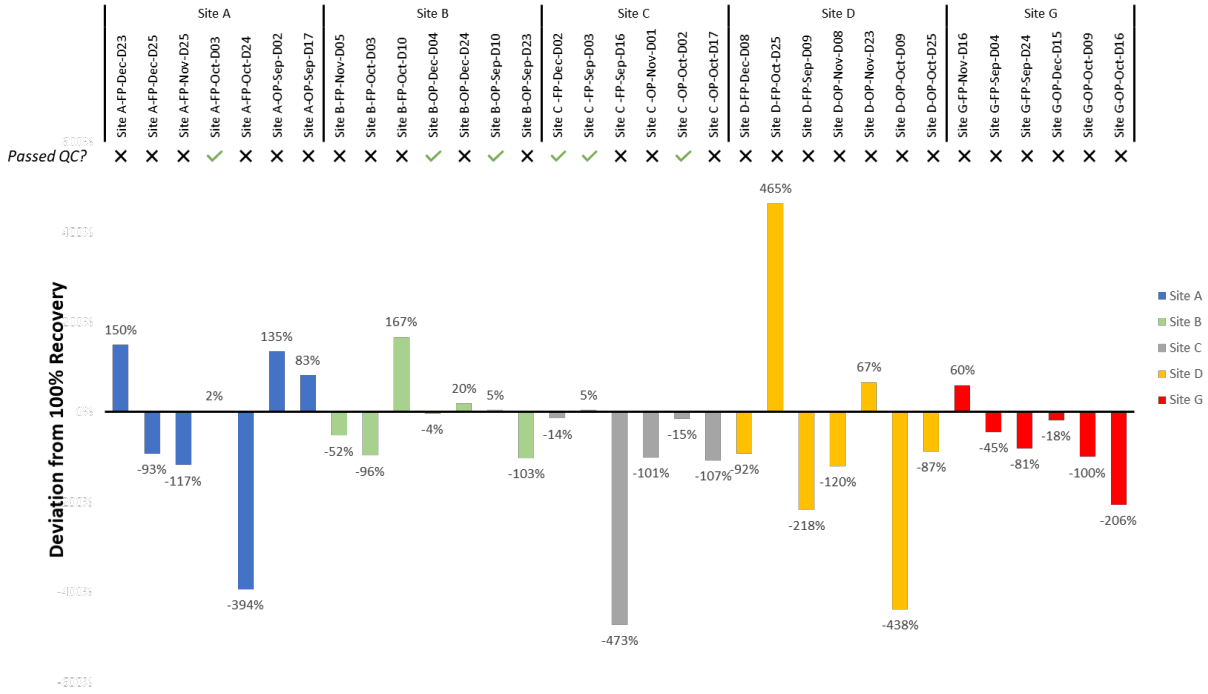


Figure 5. Visual overview of deviation from perfect recovery for quality control samples analyzed by Pace Lab over the Phase 2 part of this study. Sample ID indicates the site, treatment type, service month, and days after service. Zero percent deviation means perfect recovery of oil and grease from spiked sample matrix. Positive deviation indicates a higher than expected recovery. Percentages less than -100% indicates the spiked sample concentration was lower than measured background concentration.

The FOG concentrations for near-identical samples, as measured by Pace Analytical using EPA Method 1664B, were often highly variable. The values reported for duplicate samples were often more than 25% different. The magnitude of this variation also appeared to be associated with the service treatment type as on-site treatment samples showed a higher percent difference between duplicates when across all sites (Figure 4).

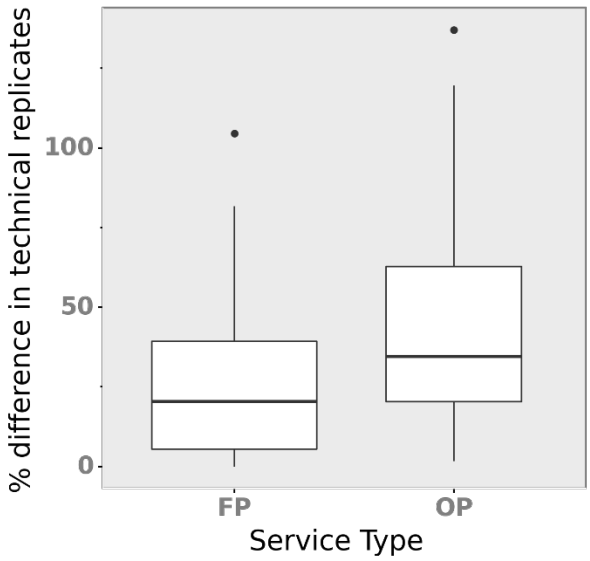


Figure 4. Overall average in the % difference in measured FOG obtained from near-identical samples collected at the same time and location from grease interceptors. Note, duplicates were taken primarily during the latter part of Phase 2 of this study to examine the precision of EPA Method 1664B after multiple batches failed to recover spike concentrations as specified by this method.

3. Methodology and Experimental Design:

3.1 Experimental Design:

The sites used in this study were selected by Grease Cycle® and were located in Cary, Durham, and Chapel Hill, North Carolina. The site reference names and a brief description are shown in Table 2. Note, all GIs had been previously maintained with on-site processing prior to the start date of this experiment, with a service frequency as also indicated in Table 2. Table 3 and Table 4 provide an overview the GI service type, date, and relevant service frequency details for the six restaurants that were monitored over sampling periods for Phases 1 and 2, respectively. The initial service treatment assignment was selected by Grease Cycle®. A more thorough description of Grease Cycle's® standard operating procedures for their on-site processing and full pump-out services can be found in the Supplemental Information at the end of this memorandum (SI 4.2).

***Table 2**. Descriptions of the restaurant sites monitored during this study and their grease interceptor tank characteristics.*

Site Identifier	*Restaurant description*	*GI tank size (gal)*	*Service frequency prior and during Phase 1(days)*	*Service frequency prior to start of Phase 2 (days)*	*Service frequency during Phase 2(days)*
Site A	Wing and pizza, sports bar.	1000	30	30	30
Site B	Sports bar	1000	30	30	30
Site C	Mediterranean restaurant	1500	60	60	30
Site D	Senior living facility	2500	60	60	30
Site E	Conference center/hotel	1000	30	n/a	n/a
Site G	Fast-food establishment	2000	n/a	90	30

Phase 1 (P1): January - March 2020. This phase included six total sites, three sites had GIs serviced on a 30-day frequency, while the other two were on 60-day cycles. Sample times were randomized around lunch between 11 AM – 3 PM. The 30-day FSEs had one of each treatment type during this phase. 60-day sites were sampled twice a week and 30-day sites were sampled three times per week. Services were performed on Thursday and sampling began at the beginning of the subsequent week. The original sampling period was set to run for approximately four months from January 2020 to May 2020. However, given the circumstances surrounding the COVID-19 pandemic, sampling was halted after two months. Thus, this first phase of sampling took place from January 27th to March 17th, 2020, the last day that dine-in services were allowed at restaurants in North Carolina.

Phase 2 (P2): September 2020 - January 2021. Of the six restaurants from P1, four remained in the study, and one additional fast-food site was added. Samples were taken at the end of the week, at approximately the same time for each site. Typical sampling consisted of three measurements during the week after pump-out, two the following two weeks, and three the week before the next service. The maintenance service treatment type was performed on Tuesdays and sampling began the following Thursday.

Table 3. *Phase 1 summary of the GI service type, date, and relevant service details for the six sites over sampling period in which the GI were serviced with the traditional full evacuation pump-out method (FP) or on-site processing (OP).*

Service Period ID	Service Type	Service Date	Sampling Dates[#]	FOG/Food Solids Removed	Returned Graywater (Gal)	Grease Layer Before Service (in)	Solids Layer Before Service (in)
SiteA-OP-P1-S1	OP	1/23	1/27 – 2/18	400	600	2	6
SiteA-FP-P1-S2	FP	2/20	2/24 – 3/17	1000	0	2	5
SiteB-FP-P1-S1	FP	1/23	1/27 – 2/18	1000	0	2	2
SiteB-OP-P1-S2	OP	2/20	2/24 – 3/17	350	650	2	3
SiteE-OP-P1-S1	OP	1/23	1/27 – 2/18	250	750	1	3
SiteE-FP-P1-S2	FP	2/20	2/24 – 3/12	1000	0	2	2
SiteC-FP-P1-S1	FP	1/24	1/27 – 3/17	1500	0	3	12
SiteD-OP-P1-S1	OP	1/23	1/27 – 3/17	1000	1500	2	1

#DD/MM , Year 2020

Table 4. *Phase 2 summary of the GI service type, date, and relevant service details for the six sites over sampling period in which the GI were serviced with the traditional complete evacuation pump-out method (FP) or on-site processing (OP).*

Service Period ID	Service Type	Service Date	Sampling Dates[#]	FOG/Food Solids Removed	Returned Graywater (Gal)	Grease Layer Before Service (in)	Solids Layer Before Service (in)
SiteA-OP-P2-S1	OP	09/22	9/24-10/17	400	600	2	2
SiteA-FP-P2-S2	FP	10/20	10/22-11/14	n/a	n/a	1	6
SiteA-FP-P2-S3	FP	11/17	11/18-12/12	n/a	n/a	2	5
SiteA-FP-P2-S4	FP	12/15	12/17-01/09*	n/a	n/a	2	3
SiteB-OP-P2-S1	OP	09/22	9/24-10/17	400	600	3	3
SiteB-FP-P2-S2	FP	10/20	10/22-11/14	n/a	n/a	2	3
SiteB-FP-P2-S3	FP	11/17	11/18-12/12	n/a	n/a	1	3
SiteB-OP-P2-S4	OP	12/15	12/17-01/09*	400	600	1	3
SiteC-FP-P2-S1	FP	09/22	9/24-10/17	n/a	n/a	10	20
SiteC-OP-P2-S2	OP	10/20	10/22-11/14	500	1000	3	11
SiteC-OP-P2-S3	OP	11/17	11/18-12/12	500	1000	4	6
SiteC-FP-P2-S4	FP	12/15	12/17-01/09*	n/a	n/a	3	12
SiteD-FP-P2-S1	FP	09/22	9/24-10/17	n/a	n/a	5	2
SiteD-OP-P2-S2	OP	10/20	10/22-11/14	1000	1500	1.5	5
SiteD-OP-P2-S3	OP	11/17	11/18-12/12	1000	1500	2	3
SiteD-FP-P2-S4	FP	12/15	12/17-01/09*	n/a	n/a	3	2
SiteG-FP-P2-S1	FP	09/22	9/24-10/17	n/a	n/a	4	10
SiteG-OP-P2-S2	OP	10/20	10/22-11/14	500	1500	2	2
SiteG-FP-P2-S3	FP	11/17	11/18-12/12	n/a	n/a	2	10
SiteG-OP-P2-S4	OP	12/15	12/17-01/09*	500	1500	2	6

#DD/MM, Year 2020, except* which is 2021

3.2 Sampling procedure and analysis:

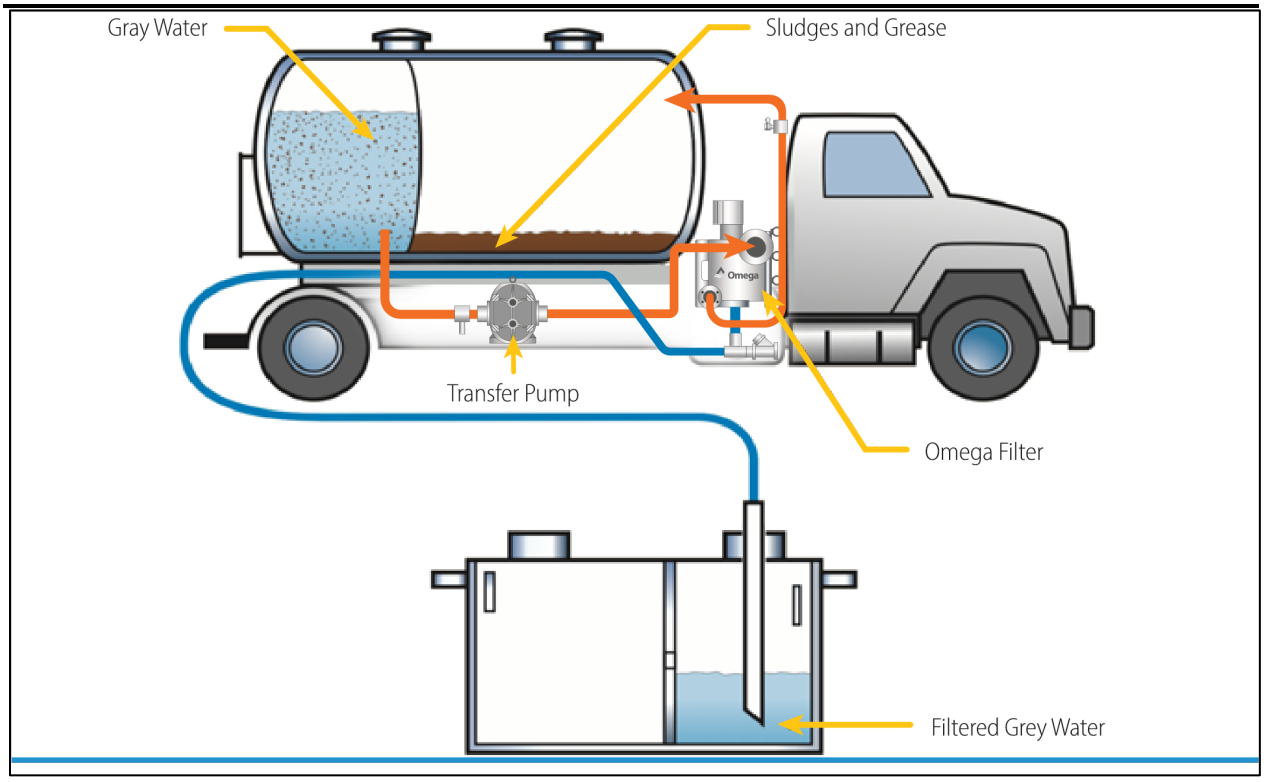
A 6 ft-plastic water sampling device was used to collect water samples from the outlet tee of the grease traps up to a depth of around 12 inches. The sampler was rinsed with tap water before and after each sampling and was rinsed with ~250-500 mL of site-specific GI outlet water before water was collected for analytical purposes. Approximately 2000-3000 mL of GI outlet water was collected during each sample period into two ~1000-mL glass jars that contained hydrochloric (HCl) acid to reduce pH to <2 for preservation purposes.

All samples were put on ice immediately after collection and stored at 4ºC. Samples were sent to Pace Analytical® lab (Charlotte, NC) within 30 days for FOG analysis via *EPA Method 1664, Revision B: n-Hexane Extractable Material (HEM; Oil and Grease)*. If GIs were not full at the sampling times shortly after service, the oil and grease concentration was considered zero since no water was flowing into sanitary sewage system, and additional measurements were taken on days following the routine schedule after the GI exhibited an effluent flow stream. The temperature of the outlet water was also measured on-site using an infrared laser thermometer and the pH of the sample was measured in lab at North Carolina State University.

While the EPA Method 1664B is known to cause issue with FOG measurements from grease interceptor waste due to potential interferences (food particulates, detergents, proteins) waste, this method is still widely used due to the lack of alternatives. This study assumes that the interference level in samples is consistent across treatment type. To roughly gauge the validity of this assumption, FOG concentrations were measured for duplicate, near-identical samples collected from GIs during the latter half of Phase 2 to assess replicability of the method. Quality control data collected over the course of the study was also analyzed to examine if any clear patterns emerged with respect to treatment type.

4. Supplemental Information

***4.1*: OMEGA SG™ (Septic & Grease) filter system graphical illustration of the on-site treatment process in which grey water is pumped into the vacuum before solids and grease are removed from GI. This grey water is then filtered through an Omega SG filter (100-µm) and returned to the GI. Grease Cycle's protocol for this process given in SI 4.2.**



Source: OMEGA Liquid Waste Solutions Patented Technology Brochure. https://www.omega-lws.com/wp-content/uploads/2019/12/Brochure-OMEGA-Liquid-Waste-Solutions-Version-3-18-11-19.pdf

Additional video on OMEGA SG™ (Septic & Grease) technology: https://vimeo.com/380786532

***4.2* Grease Cycle's® pump-out protocol for complete evacuation (FP) and on-site processing (OP) as provided by Dylan Gehrken, Grease Cycle® President, via email communication on 5/22/2020.**

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GREASECYCLE

Grease Trap Pumping Protocol

Protocol for Grease Trap – Complete Evacuation

- The driver locates the grease trap
- Removes all manhole covers, places safety cones near any open manway.
- Uses the 'sludge judge' tool to determine the inches of solids on the bottom & inches of grease on top
- Turns on the 'Power take off' (PTO) in the truck to divert the engine power to vacuum
- Opens the vacuum valve and introduces the vacuum hose to 2 feet below the surface of liquid.
- While the contents of the trap are being extracted, the driver scrapes down the baffle & side walls, lowers hose down as liquid level drops.
- Once the contents have been extracted, the driver vacuums the solids left on the floor of the trap
- The driver returns the hose to the truck, closes valve & turns off PTO
- Replaces the manhole covers
- Fills out the Manifest (Business / Facility name, address, date, time, gallons collected, inches of grease on top, inches of solids on bottom, print name & sign)
- Leaves the pink copy of manifest at the facility

Protocol for Grease Trap – On Site Processing

- The driver locates the grease trap
- Removes all manhole covers, places safety cones near any open manway.
- Uses the 'sludge judge' tool to determine the inches of solids on the bottom & inches of grease on top. After measuring the lowest depth of grey water with sludge judge, the driver marks this correlating depth on hose to identify how deep to place the hose beneath surface. This step enables the driver to maximize the amount of greywater extracted while avoiding the introduction of grease and food solids to the greywater portion of the vacuum tank.

- The driver turns on the PTO, introduces the vacuum hose to the maximum depth of the grey water & opens the valve
- The driver monitors the clear section in the hose, if anything other than clear water is visible through this site glass, the driver presses the sludge button on the remote to divert flow to the solids chamber.
    - *Note: there is also a turbidity sensor on the truck that also acts as a failsafe feature to prevent solids from being collected with grey water; if triggered, it will close the grey water compartment valve and open the valve for the solids compartment.*
- Once the driver has pressed the button on the remote control indicating that the truck must switch from its grey water harvesting mode to its solids evacuation mode, the material only flows into the solids compartment, no material can enter the grey water compartment at this point. The driver vacuums out the remaining food solids and grease. Simultaneously, the driver scrapes down the baffles and side walls and evacuates that material as well.
- Once the trap is empty, the driver starts the filtration process for the greywater that will be re-introduced by pushing the filtration button on the remote control. The driver ensures the hose is secure and pointed into the inlet compartment of the grease trap. During this step, the grey water is automatically pumped out of the grey water compartment, flows through a centrifuge spinning at 2100 RPM (relative centrifugal force of ~560) and flows through a 100-um filter at a rate ~135 gallons per minute to remove any remaining food and grease particles.
    - *Note: The truck has a baffled grey water compartment and outlet-T so a portion of the gray water/solids will temporarily remain in the grey water chamber. This configuration also allows for partial gravity-based solid separation prior to centrifugation and filtration*
    - *Note: There is a pressure sensor inside the filtration unit, if it exceeds 31 psi, a valve connected to the solids compartment will open and close quickly purging the accumulated solids on the filtration membrane. This material flows into the solids compartment.*
- Once the filtration is complete and all filtered grey water is returned to the inlet compartment of the grease trap, the driver runs a cleaning cycle for the grey water compartment of the truck. This cycle purges the remaining water/settled solids/scum that were left in the grey water compartment of the truck into the solids compartment.
- The driver places the hose back on the truck, closes valve & turns off PTO
- The driver fills out the Manifest (Business / Facility name, address, date, time, gallons collected, inches of grease on top, inches of solids on bottom, amount of sludge hauled away, amount of grey water reintroduced, print name & sign)
- Leaves the pink copy of manifest at the facility