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January 9, 2007

Mr. Michael Jones
Emissions, Monitoring and Analysis Division (C339-02)
Office of Air Quality Planning and Standards
U.S. Environmental Protection Agency
Research Triangle Park, NC 27711

Dear Mr. Jones:

I have enclosed a copy of the paper we recently presented for "Collection and Analysis of Acrolein using Compendium Method TO-15". We presented this paper at the NEMC in Washington, DC (August, 2006), and the QA Region 6 Conference, in Dallas, TX (October, 2006).

If you have any questions or comments, please call me at (919) 468-7924.

Sincerely,

Julie L. Swift

Julie L. Swift
Senior Program Manager

cc: Dennis Mikel, EPA

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Collection and Analysis of Acrolein using Compendium Method TO-15

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ABSTRACT

Acrolein, because of its polarity and reactivity, is recovered more efficiently in canister samples using EPA Compendium Method TO-15 with Gas Chromatography/Mass Spectroscopy (GC/MS) and selective ion monitoring (SIM) than the previously used Compendium Method TO-11A. Determination of acrolein by Method TO-11A is less accurate because of the low acrolein capture efficiency and the tautomerization of the acrolein hydrazone derivative on acidified 2,4-dinitrophenylhydrazine (DNPH) cartridges. Eastern Research Group (ERG) has demonstrated the superior performance of canister sampling through the results of a study that introduced a gaseous acrolein standard, representative of "real world" samples, concurrently into DNPH cartridges and canisters. A field study comparison of the collection efficiency of acrolein using Method TO-15 and Method TO-11A will be presented for samples simultaneously collected throughout the country for one year in canister and cartridge samples. Data from Method TO-15 collection and analysis of ambient air across the United States is presented to show the recovery of acrolein in canister samples. Audit results are presented proving the accuracy of acrolein from canister samples using Method TO-15.

INTRODUCTION

Acrolein is listed as one of the four core compounds for the National Air Toxics Trends Stations (NATTS) throughout the country. Because of this, and because of the reactivity and toxicity of acrolein in ambient air, ERG has been studying new techniques to collect and analyze acrolein more accurately. Method TO-11A has been the standard method for the analysis of aldehydes in ambient air. ERG has not reported analytical results for the measurement of acrolein since 1999 because of its unstable retention on the DNPH coated adsorbent cartridges used for Compendium Method TO-11A. An Addendum to Method TO-11A was issued March 1999 to remove acrolein from the analyte list. Recently, ERG has determined that acrolein can be analyzed more accurately using Compendium Method TO-15 from air samples in canisters. Method TO-15 is an analytical method currently used for the sampling and analytical procedures for the measurement of subsets of volatile organic compounds that are included in the 1989 hazardous air pollutants (HAPs) listed in the Title III of the Clean Air Act Amendments of 1990.

The following data presents the comparison of two compendium methods as well as the precision and accuracy following Method TO-15.

Methodology

DNPH treated cartridges and SUMMA canisters were used to collect ambient samples at the same sampling site. These samples are taken at the same time on the same sampling systems. The canisters and cartridges were collected for 24 hours. Canisters collect 6L of whole air,

whereas the carbonyl tubes concentrate and stabilize carbonyl compounds from a volume of air. ERG collects and analyzes all canister samples at a vacuum from 1 to 12 inches of Hg to ensure volatile organic compounds remain in the vapor phase. If the canister is pressurized, condensation of water from high-humidity samples may cause fractional losses of polar, water-soluble compounds.

Method Development – Method TO-11A

Method TO-11A, the standard method for the analysis of aldehydes in ambient air, demonstrates low recovery for acrolein. In order to verify this, ERG used a certified standard of gaseous acrolein rather than liquid DNPH derivative spikes to simulate a real world sample. The certified cylinder was used to sample underivatized acrolein through a sampling system onto the DNPH cartridges.

Four sample sets (i.e., duplicate paired carbonyl cartridges) were collected from a common test manifold, one set every 24 hours over a period of 4 days. After the samples were collected, the cartridges were extracted within 7 days of sampling and analyzed within 30 days of extraction. Table 1 presents the sample recovery results. Because the recovery was consistently below acceptable limits, ERG decided to evaluate acrolein analysis by TO-15.

Table 1: Carbonyl Recovery Data - Modified Method TO-11A, Gaseous Samples.

Sample	Acrolein[a] (two peaks)	
	Conc. Recovered (ppbv)	Percent Recovery
Sample Run 1 – Primary	2.55	43%
Sample Run 1 – Duplicate	2.18	37%
Sample Run 2 – Primary	2.59	44%
Sample Run 2 – Duplicate	2.33	39%
Sample Run 3 – Primary	2.47	42%
Sample Run 3 – Duplicate	2.32	39%
Mean ± Standard Deviation	2.41 ± 0.16	41% ± 3%

[a] Acrolein nominal concentration is 5.92 ppbv.

Method Development – Method TO-15

Acrolein was measured using Method TO-15 without altering the analytical method currently used to determine the toxics compounds reported to the EPA for the Urban Air Toxics Monitoring Program (UATMP). Acrolein was stable in calibration standards and could be separated from other Method TO-15 compounds using conditions in the current method.

The goal was to try to determine acrolein at low enough concentrations (at or below risk levels) without major modifications to the current method. Reaching low detection limits required the

use of Gas Chromatography/Mass Spectroscopy (GC/MS) with selective ion monitoring (SIM), monitoring Ions 56 (Quant Ion), 55, 29, 27, and 26. The Method Detection Limits (MDLs) were determined at the ERG analytical laboratory using 40 CFR, Part 136 procedures. ERG's experimentally determined MDL for acrolein is 0.08 ppbv (0.18 µg/m^3) for 2006.

To evaluate field sample collection, a canister sample was collected through a NATTS TO-15 sampler spiked with gaseous acrolein. Results from the analysis of this single sample showed acceptable recovery for acrolein of 100 ± 10 percent.

ERG then examined acrolein recovery and stability using Method TO-15. Multiple canisters from different manufacturers were spiked with know amounts of acrolein and analyzed several times over a period of 4 weeks. The relative percent difference (RPD) between time zero (Week 1) and subsequent analysis for this study is shown in Table 2.

Table 2: Acrolein stability in canisters expressed in RPD.

Canister ID	Relative Humidity	Concentration (ppbv)	Week 1 RPD	Week 2 RPD	Week 3 RPD	Week 4 RPD
1-1	10%	Low – 0.5	3.4	7.1	ND	ND
1-2		High – 10	7.6	13	3.1	17
1-3	80%	Low – 0.5	15	15	ND	ND
1-4		High – 10	8.7	8.7	6.6	7.9
2-1	10%	Low – 0.5	21	18	24	24
2-2		High – 10	8.2	NA	17	23
2-3	80%	Low – 0.5	0	8.9	2.1	**28**
2-4		High – 10	6.9	7.2	6.2	21
3-1	10%	Low – 0.5	3.0	0	5.9	19
3-2		High – 10	21	**28**	**36**	**47**
3-3	80%	Low – 0.5	2.8	11	**37**	ND
3-4		High – 10	6.0	4.2	11	16
4-1	10%	Low – 0.5	**47**	**71**	**80**	**85**
4-2		High – 10	6.5	10.2	12	10
4-3	80%	Low – 0.5	2.3	9.3	4.4	14
4-4		High – 10	1.8	1.5	7.9	14
		Average	10	14	18	**25**

NA = Not applicable – analytical malfunction.
ND = Not detected.
NOTE: Results listed in **bold** are outside the required RPD of 25%.

The overall average acrolein percent difference over four weeks increased steadily from 10 to 25%. Although the stability at the high concentration and humidity is less than the low

concentration and humidity, the study does support the ability to report acrolein concentrations for NATTS and UATMP sites across the country following Method TO-15 (GC/MS/SIM).

After the stability study was completed, the Rhode Island Department of Health Laboratory reported that the acrolein concentrations increased in ambient air canisters within a short period after collection. To investigate the Rhode Island observation, ERG performed a short-term stability study. Grab samples were taken on an overpass above a heavily traveled highway. This allowed elevated levels of acrolein from mobile source emissions to be present in the canisters. Table 3 presents the results of this study. Because of similar reactivity levels for acrolein and 1,3-butadiene, recoveries for both compounds are presented. Results are presented for the analysis performed directly after sampling, 24 hours after sampling, and for pressurized samples. As shown, there were no statistical differences in the results with the exception of Canister 2080, which had variance over the NMP data guidelines of 25%.

Table 3: Ambient air stability study.

ANALYZED IMMEDIATELY AFTER COLLECTION				
Canister ID 068				
Time	**Acrolein (ppbv)**	**RPD**	**1,3-Butadiene (ppbv)**	**RPD**
6/23/2006 13:04	0.29		2.15	
6/23/2006 15:27	0.27	7.1	2.05	4.8
6/23/2006 17:49	0.23	23	2.02	6.2
Canister ID EP0763				
Time	**Acrolein (ppbv)**	**RPD**	**1,3-Butadiene (ppbv)**	**RPD**
6/23/2006 14:15	0.55		3.18	
6/23/2006 16:38	0.51	7.5	3.10	2.5
6/23/2006 18:59	0.51	7.5	3.07	3.5
ANALYZED 24 HOURS AFTER COLLECTION				
Canister ID 2080				
Time	**Acrolein (ppbv)**	**RPD**	**1,3-Butadiene (ppbv)**	**RPD**
6/2/2006 21:12	0.44		2.95	
6/3/2006 4:05	0.51	15	2.99	1.3
6/3/2006 20:48	0.56	24	2.99	1.3
6/4/2006 1:30	0.55	22	2.76	6.7
6/4/2006 18:13	0.46	4.4	2.80	5.2

Canister ID ER019				
Time	**Acrolein (ppbv)**	**RPD**	**1,3-Butadiene (ppbv)**	**RPD**
6/2/2006 22:22	0.33		1.69	
6/3/2006 5:16	0.31	6.3	1.66	1.8
6/3/2006 21:58	0.32	3.1	1.67	1.2
6/4/2006 2:41	0.32	3.1	1.61	4.8
6/4/2006 19:23	0.35	5.9	1.66	1.8
ANALYZED 24 HOURS AFTER COLLECTION – INITIALLY PRESSURIZED				
Canister ID TX007				
Time	**Acrolein (ppbv)**	**RPD**	**1,3-Butadiene (ppbv)**	**RPD**
6/5/2006 10:24 2.5 psi	1.18		6.2	
6/6/2006 13:45 (0" Hg)	1.23	4.1	5.84	6.0
6/6/2006 18:29 (<0 "Hg)	1.28	8.1	6.85	10
6/6/2006 23:12 (<0 "Hg)	1.18	0	5.58	11
6/7/2006 3:56 (<0" Hg)	1.18	0	5.59	10
6/7/2006 8:41 (< 0" Hg)	1.23	4.1	5.67	8.9
Canister ID 2240				
Time	**Acrolein (ppbv)**	**RPD**	**1,3-Butadiene (ppbv)**	**RPD**
6/5/2006 9:11 (2.5 psi)	1.85		8.87	
6/6/2006 14:56 (0" Hg)	1.9	2.7	8.33	6.3
6/6/2006 19:39 (<0 "Hg)	1.83	1.1	8.35	6.0
6/7/2006 0:23 (<0 "Hg)	1.88	1.6	8.2	7.9
6/7/2006 5:07 (<0" Hg)	1.86	0.5	8.26	7.1
6/7/2006 9:52 (<0 "Hg)	1.77	4.4	7.76	13

NOTE: Results listed in **bold** are outside the required RPD of 25%.

Compendium Method Comparison

ERG has collected acrolein from the National Monitoring Program sites (NMP) since July 2005 following Method TO-15. To demonstrate the percent differences between the two methods, Table 4 presents results for Method TO-11A versus TO-15. Percent recovery of Method TO-11A assumes the Method TO-15 results represent acrolein concentration in these ambient air samples.

Table 4: Method TO-11A versus Method TO-15.

Site	Date	TO-11A (ppbv)	TO-15 (ppbv)	% Recovery of TO-11A
Bountiful, UT	9/13/05	0.114	3.17	3.6%
Loudon, TN	10/13/05	0.040	1.10	3.6%
Providence, AL	10/19/05	0.059	1.20	4.9%
Birmingham, AL	10/19/05	0.137	1.46	9.4%
Shillar Park, Chicago, IL	10/31/05	0.085	1.08	7.9%
Madison, WI	11/12/05	0.049	0.47	10%
Barceloneta, Puerto Rico	11/12/05	0.024	0.84	2.9%
Minneapolis, MN	11/18/05	0.018	1.21	1.5%
Camden, NJ	12/24/05	0.186	0.78	24%
New Brunswick, NJ	12/30/05	0.040	1.18	3.4%
Sioux Falls, SD	2/28/06	0.089	0.56	16%
Grand Junction, CO	3/24/06	0.099	0.58	17%
Austin, TX – site 1	4/23/06	0.054	0.48	11%
Austin, TX – site 2	4/23/06	0.037	0.39	9.5%
Austin, TX – site 3	4/23/06	0.035	0.58	6.0%
Austin, TX – site 4	4/23/06	0.036	0.53	6.8%
Austin, TX – site 5	4/23/06	0.089	0.45	20%
Custer Park, SD	5/17/06	0.044	0.74	5.9%
Elizabeth, NJ	5/29/06	0.192	0.66	29%
Tulsa, OK	5/29/06	0.121	0.82	15%
			Average	10%

The recoveries of acrolein are clearly much lower for Method TO-11A than for Method TO-15 in real field samples.

Method TO-15 Field Sample Results for Acrolein

Forty-four NMP sites collected samples from July 2005 to September 2006. Some monitors were placed near the centers of heavily populated cities (e.g., Chicago, IL and St. Louis, MO), while others were placed in moderately populated areas (e.g., Madison, WI and Custer, SD). Acrolein concentrations measured during this time varied significantly from monitoring location to monitoring location. The proximity of the monitoring locations to different emission sources, especially industrial facilities and heavily traveled roadways, often explains the observed spatial variations in ambient air quality.

A total of 2,044 acrolein measurements (including duplicate and replicate samples) were detected at the 43 NMP sites from July 2005 to mid-September 2006. Five hundred and sixty-nine of these samples were taken at four sites during the clean up after Hurricane Katrina. Of the

2,044 acrolein measurements, 59% of these results were detected above the MDL and 1.7% of these concentrations were below the MDL. The average acrolein concentration was 1.49 µg/m^3. Table 5 presents the sample count, maximum value, minimum detected value, median, mean for this data set.

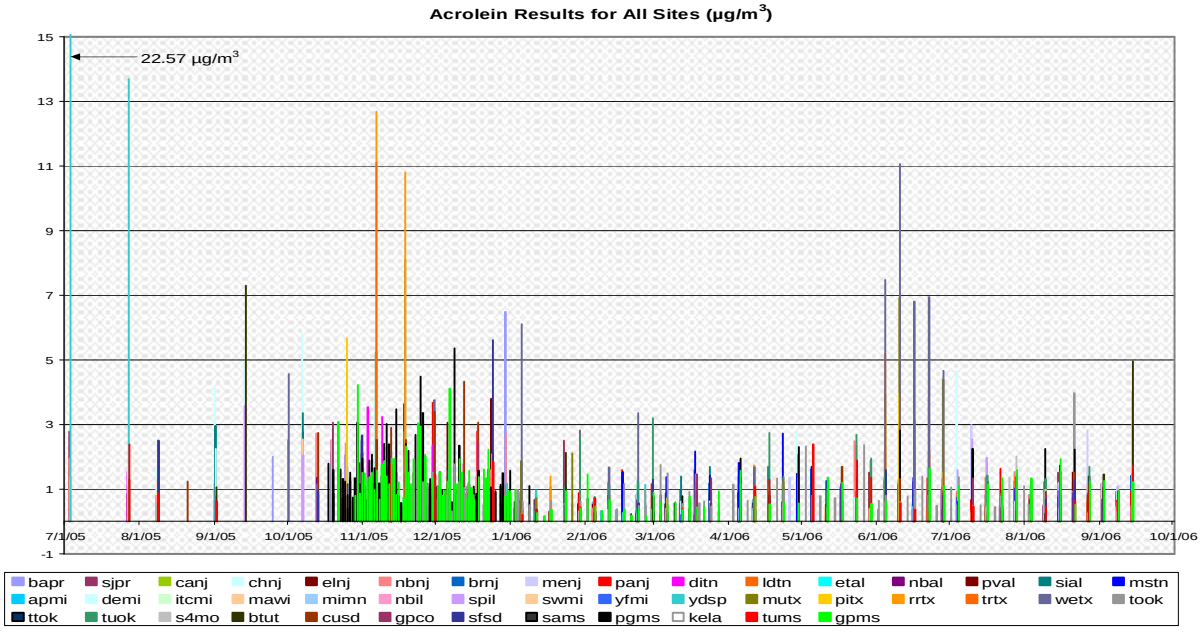
Table 5: Analytical Results for samples collected between July 2005 and mid-September 2006.

Site ID	Frequency of Detects	Maximum Value (µg/m^3)	Minimum Value (µg/m^3)	Median (µg/m^3)	Average (µg/m^3)
Sault Sainte Marie, MI	100%	1.04	0.35	0.40	0.55
Tulsa, OK (site 1)	100%	3.98	0.39	0.97	1.10
Tulsa, OK (site 2)	100%	2.83	0.58	1.15	1.38
Tulsa, OK (site 3)	100%	3.20	0.37	1.31	1.47
Austin, TX (site 1)	92%	13.25	0.71	4.05	4.73
Austin, TX (site 2)	88%	20.54	0.60	2.22	5.18
Peterson, NJ (site 2)	83%	2.99	0.25	1.01	1.25
Loudon, TN (site 2)	83%	2.71	0.32	1.15	1.19
Austin, TX (site 5)	80%	11.64	1.04	5.39	5.67
Austin, TX (site 3)	77%	15.85	0.28	1.48	3.05
Peterson, NJ (site 3)	76%	3.68	0.35	0.85	1.21
Peterson, NJ (site 1)	75%	2.48	0.60	0.87	1.05
Gulf Port, MS	74%	4.23	0.16	1.10	1.18
Kenner, LA	71%	2.37	0.18	0.78	0.85
North Birmingham, AL	70%	2.14	0.32	0.81	0.94
San Juan, Puerto Rico	70%	2.78	0.35	0.82	0.98
Loudon, TN (site 1)	69%	2.53	0.30	0.62	0.75
Pascagoula, MS	67%	3.47	0.14	0.95	1.16
Birmingham, AL (site 2)	64%	3.36	0.23	0.92	1.12
Austin, TX (site 4)	64%	12.17	0.35	2.30	3.57
Tupelo, MS	61%	2.39	0.14	0.61	0.85
Custer Park, SD	61%	5.73	0.28	1.17	1.44
Detroit, MI (site 2)	58%	2.25	0.18	0.51	0.66
Stennis Airport, MS	58%	5.36	0.16	0.94	1.11
New Brunswick, NJ	56%	2.88	0.30	0.82	1.19
Chester, NJ	56%	5.82	0.12	0.85	1.45
Bountiful, UT	56%	7.29	0.21	0.83	1.22
Elizabeth, NJ	56%	3.80	0.12	0.58	0.83
Grand Junction, CO	54%	3.06	0.16	0.78	1.02
Birmingham, AL (site 1)	52%	1.91	0.18	0.64	0.82
Barceloneta, Puerto Rico	51%	6.49	0.14	0.78	1.05

Site ID	Frequency of Detects	Maximum Value (µg/m^3)	Minimum Value (µg/m^3)	Median (µg/m^3)	Average (µg/m^3)
Dickson, TN	50%	3.54	0.62	2.20	2.22
El Paso, TX	50%	22.06	0.23	0.77	2.52
Minneapolis, MN	47%	2.78	0.18	0.78	0.96
Camden, NJ	46%	1.79	0.21	0.69	0.71
Sioux Falls, SD	46%	5.61	0.37	0.89	1.17
St. Louis, MO	40%	4.00	0.14	0.63	0.89
Chicago, IL (site 2)	37%	3.57	0.25	0.97	1.30
Chicago, IL (site 1)	28%	2.94	0.16	0.44	0.69
Providence, AL	28%	2.76	0.16	0.32	0.66
Detroit, MI (site 3)	20%	1.31	1.31	1.31	1.31
Madison, WI	19%	6.33	0.35	0.67	1.72
Detroit, MI (site 4)	14%	0.58	0.21	0.39	0.39
Detroit, MI (site 1)	11%	1.08	1.08	1.08	1.08
Average	60%	5.06	0.34	1.11	1.49

The highest concentration was taken at El Paso, TX, at 9.59 ppbv (22.06 µg/m^3). The samples taken during the clean up for Hurricane Katrina, were collected on 1-in-1, 1-in-3, and 1-in-6 day schedules. This data is presented with all of the data from the NMP sites in Figure 1. Acrolein results from the NMP and Katrina sites are relatively the same and show similar increases and decreases over time.

Figure 1: Acrolein Results for samples collected between July 2005 and mid- September 2006.



Data Quality Control and Assurance

An audit containing acrolein was prepared in November 2005 by US EPA and sent to ERG for analysis. Table 6 presents a summary of the audit report. The acrolein concentration determined by ERG resulted in a 22.3 percent difference from the nominal value spiked in the canister. The 'True' value was based on the results of 3 analyses performed by Alion/EPA(ORD).

Table 6: Acrolein audit results.

Compound	ERG (ppbv)	True (ppbv)	% Difference	Uncertainty
Acrolein	1.48	1.21	22	± 11%
1,3-Butadiene	1.84	1.44	28	± 0.2%

NOTE: The percent uncertainty is the coefficient of variation for the three replicate analyses.

Precision of the analytical and sampling technique was determined by the analysis of duplicate sampling episodes and replicate analysis. A duplicate sample (i.e., a sample collected simultaneously with a primary sample using the same sampling system) provides information on the potential for sampling variability. Replicate analyses of these duplicate samples provide information on the potential for analytical variability. The duplicate and replicate analysis results were complied from sites sampling in the NMP from July 2005 through June 2006.

The data is presented in Relative Percent Difference (RPD) and the Coefficient of Variation (CV). The RPD expresses average concentration differences relative to the average concentrations detected during replicate analyses. The RPD is calculated as follows:

$$RPD = \frac{|X_1 - X_2|}{\overline{X}} \times 100$$

Where:

X_1 is the ambient air concentration of a given compound measured in one sample;

X_2 is the concentration of the same compound measured during collocated analysis; and

$\overline{X}$ is the arithmetic mean of X_1 and X_2.

As this equation shows analyses with low variability have lower RPDs (and better precision), and analyses with high variability have higher RPDs (and poorer precision). The RPD method quality objective for all data from the NMP is 25 percent. The replicate data shows very good precision with a few outliers presented. As shown in Table 7, the overall compound by compound average shows very good precision for replicate analyses at 3.5 percent. This table shows the results after the outliers were removed, based on the 95% confidence level.

Table 7: Replicate Analysis Results (July 2005 to mid-September 2006).

Site ID	# of Replicates	Median (RPD)	Average (RPD)	Percent Standard Deviation
Loudon, TN	6	14	11	8.5
San Juan, Puerto Rico	6	12	11	9.7
Dickson, TN	1	11	11	0
Austin, TX (site 2)	1	10	10	0
Kenner, LA	17	9.5	7.6	6.3
Austin, TX (site 1)	1	6.0	6.0	0
Austin, TX (site 3)	1	5.9	5.9	0
Birmingham, AL (site 2)	4	5.9	6.5	7.6
Austin, TX (site 4)	1	4.1	4.1	0
Peterson, NJ (site 2)	2	4.1	4.1	2.3
Stennis Airport, MS	13	4.0	4.1	2.9
Peterson, NJ (site 1)	4	3.4	3.8	4.4
Pascagoula, MS	15	2.1	3.4	3.8
Austin, TX (site 5)	20	2.1	2.4	2.5
Sioux Falls, SD	6	1.2	1.9	2.3
Barceloneta, Puerto Rico	7	0	2.0	3.6
Bountiful, UT	8	0	0.13	0.38
Chester, NJ	10	0	0.66	1.4
Custer Park, SD	7	0	0.95	1.8
Detroit, MI	15	0	0	0
Elizabeth, NJ	13	0	0	0
Grand Junction, CO	9	0	1.0	2.2
Gulf Port, MS	12	0	0.38	0.69
North Birmingham, AL	3	0	2.5	4.3
New Brunswick, NJ	8	0	0.31	0.88
Peterson, NJ (site 3)	4	0	0	0
St. Louis, MO	9	0	0	0
Tupelo, MS	10	0	0	0
El Paso, TX	18	0	0.10	0.42
Average	8	3.3	3.5	2.3

The duplicate data shows an over all acceptable method precision that is below the required 25% target. For individual results, factors such as unknown sampler/operator errors or canister variance are possible explanations for the higher average RPD results. Table 8 presents the overall data average results at 6.8%. This table shows the results after the outliers were removed, based on the 95% confidence level.

Table 8: Duplicate Statistical Data Results (July 2005 to mid-September 2006).

Site ID	# of Duplicates	Median (RPD)	Average (RPD)	Percent Standard Deviation
Barceloneta, Puerto Rico	3	**40**	**31**	27
Sioux Falls, SD	4	24	**26**	30
Kenner, LA	8	15	19	17
Bountiful, UT	4	11	25	38
San Juan, Puerto Rico	2	6.8	6.8	9.6
Loudon, TN	3	6.3	4.6	4.0
Austin, TX (site 5)	11	5.1	8.4	9.9
Pascagoula, MS	8	4.5	4.8	4.6
Custer Park, SD	4	3.9	4.2	4.9
Grand Junction, CO	5	3.9	11	18
Gulf Port, MS	10	3.5	12	17
Peterson, NJ (site 1)	4	2.5	6.6	10
New Brunswick, NJ	6	1.7	6.1	8.2
Stennis Airport, MS	10	0.71	7.4	12
Camden, NJ	2	0	0	0
Chester, NJ	4	0	0	0
Elizabeth, NJ	6	0	0	0
Peterson, NJ (site 2)	1	0	0	NA
Peterson, NJ (site 3)	4	0	0.35	0.71
Loudon, TN (site 2)	1	0	0	NA
North Birmingham, AL	1	0	0	NA
Birmingham, AL (site 2)	1	0	0	NA
Tupelo, MS	4	0	0.39	0.79
Detroit, MI	7	0	5.9	8.6
Chicago, IL	3	0	0	0
El Paso, TX	11	0	3.9	6.9
St. Louis, MO	4	0	0	0
Average	5	4.7	6.8	9.9

NOTE: Results listed in **bold** are outside the required RPD of 25%.

SUMMARY

ERG has determined that Method TO-11A results for acrolein show a significant negative bias. ERG's audit recovery and stability testing demonstrate acceptable results using Method TO-15 for the analysis of acrolein. Comparison to Method TO-11A demonstrated the acceptable

recovery of Method TO-15 analysis using Gas Chromatography/Mass Spectrometry/Selected Ion Monitoring (GC/MS/SIM) for analysis of real field samples for acrolein.

Replicate and Duplicate results are within the 25% criteria set for the NATTS program. Long-term studies need to be completed to see if trends are seen from year to year. The overall study, including stability, retainability, precision and accuracy, appear to indicate that Compendium Method TO-15, using GC/MS and SIM analysis, is an acceptable method for the determination of acrolein.

ACKNOWLEDGMENTS

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REFERENCES

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