



Clean Air Status and Trends Network

Fourth Quarter 2020 Quality Assurance Report

Summary of Quarterly Operations (October through December) with 2020 Annual Summary

EPA Contract No. EP-W-16-015

Introduction

This quarterly report summarizes results from the Clean Air Status and Trends Network (CASTNET) quality assurance/quality control (QA/QC) program for data collected during fourth quarter 2020. It also provides an annual summary that includes data from the three previous quarters. The various QA/QC criteria and policies are documented in the CASTNET Quality Assurance Project Plan (QAPP; Wood, 2020). The QAPP is comprehensive and includes standards and policies for all components of project operation from site selection through final data reporting. It is reviewed annually and updated as warranted.

Significant Events for 2020

Wood recommended that Anne Glubis replace Ann Bernhardt as the CASTNET Quality Assurance Supervisor after Ann Bernhardt was promoted within the Wood corporate structure. EPA approved Wood's request for a change in Key Personnel, and Anne Glubis formally assumed the role of the CASTNET Quality Assurance Supervisor on January 8, 2020.

The annual management review presentation in support of the International Organization for Standardization (ISO)/International Electrotechnical Commission (IEC) 17025:2017 accreditation by the American Association for Laboratory Accreditation (A2LA) was completed and distributed to the management team. The meeting on the 2019 management review presentation, as required to maintain Wood's ISO/IEC accreditation by A2LA, was held May 14, 2020. Wood upper management continues to support CASTNET. In response to the meeting, the CASTNET Laboratory Operations Manager (LOM) is looking into options for Wood to purchase a new ammonia analyzer.

Documentation for the 2020 renewal of the ISO/IEC 17025:2017 accreditation by the A2LA was completed and submitted to A2LA. A2LA accepted Wood's annual submittal. Wood's 17025:2017 ISO/IEC accreditation is current through May 2021.

Routine review of records led to identification of a subset of site operators needing official training records. The site operators were contacted, and training materials were provided by Wood. Training materials included both technical and quality management system materials. Site operators also received training questionnaires for discussion with and approval by CASTNET field personnel.

Wood implemented a new procedure designed to identify site operators needing training. When site operator contact information is added or updated, a "ticket" is now generated to alert field personnel of a potential need for training. The ticket remains open and active until field personnel verify the site

operator is up-to-date with training. The CASTNET QA Manager developed a team-accessible matrix that includes site operator technical training and quality management system training.

The new ozone flagging codes were used beginning with the January 2020 ozone data submitted to AQS. The flags and AQS definitions are as follows:

OZONE_F	AQS FLAG	AQS DEFINITION
B	BA	Maintenance/routine repairs
C	BC	Multi-point calibration
F	AV	Power failure
H	AN	Machine malfunction
I	DA	Aberrant data
J	AS	Poor quality assurance results
M	BG	Missing data
T	AZ	QC audit
Y	AY	QC control points (zero/span)

Wood's analytical laboratory uses a simulated rainwater standard reference material (SRM) designed for CASTNET target analytes as part of its QC checks. High Purity Standards supplies the SRM. Wood noted that its results did not match the SRM certificate of analysis while solutions provided by AccuStandard matched their provided certificates. The CASTNET LOM contacted the laboratories associated with ECCC and NADP and learned those laboratories were also having problems with the High Purity Standards SRM. The LOM contacted High Purity Standards who agreed to send a reformulation of the SRM.

MTL Corp ran out of nylon filters from Lot 709 and did not notify Wood of the impending change to Lot 710. Wood learned of the change from ECCC and ordered additional filters from Lot 710 to begin acceptance tests. The filters passed laboratory acceptance tests. The filters from Lot 710 were deployed at the MCK231, KY co-located site for comparison with Lot 709 filters. Field testing ran from March 3, 2020 through April 7, 2020. Results from the 5-week co-located field comparison of the MTL nylon filters from Lot 709 and Lot 710 at the MCK131/231, KY site indicated that nylon sulfate was slightly higher for the Lot 710 nylon filters. The precision of nylon sulfate measurements is historically low. Since measured concentrations were very low, Wood decided to extend the co-located comparison study for an additional four months, which began on June 2, 2020, and ran through the sampling week that began on September 29, 2020. Results from the longer study showed the two lots are comparable. Wood will begin using filters from Lot 710 for March 2021 sampling activities. Wood maintains approximately a one-year supply of filters in reserve to allow for acceptance testing and verification of comparability when changes occur.

The CASTNET QAPP Revision 9.3 was approved by EPA during March 2020.

Providing a safe working environment is one of Wood's goals. During March, Wood responded to the COVID-19 crisis by providing equipment and IT support for Wood personnel to work from home. Laboratory and field personnel began staggering hours in the respective laboratories to promote

social distancing. Additional cleaning is being done for frequently touched surfaces. CASTNET field operations adapted to the ongoing problems caused by the COVID-19 pandemic. Wood prepared COVID-19 safety guidelines for calibration and repair trips to CASTNET sites. The guidelines include personal protective equipment requirements and safety procedures. During 2020, calibrations were rescheduled as needed to adhere to stay-at-home safety precautions and state-level quarantine restrictions. Audits of sites by non-CASTNET personnel adhered to COVID-19 health and safety recommendations including social distancing.

The EEMS first quarter report indicated a siting criteria violation at the SUM156, FL site, which was observed using an EEMS remote controlled drone. Wood checked the site for trees and other obstacles and took photographs, which were provided to EPA. Wood coordinated with the U. S. Forest Service for removal of the trees that were in or near violation.

Wood implemented programming changes to the iCASTNET data management system. This application is used by field, data, and quality assurance personnel to manage field activities and data collection and validation. During June, ozone and trace gas data review and validation activities were done in duplicate using the normal procedure and iCASTNET to verify the accuracy of iCASTNET. As accuracy was verified, activities were transferred to iCASTNET. Additionally, electronic data review, validation summary, and data submittal forms were tested for utility and ease of use prior to being incorporated into the review process.

Wood field, data, and QA personnel discussed the handling of flagging for zero/span/precision (zsp) QC checks invalidated or not invalidated due to moisture. The majority of the zsp checks are stabilizing after a sufficient zero air purge. Comments included in iCASTNET problem tickets will clearly indicate which ones are stabilizing versus failed checks that indicate problems with ambient concentrations.

EPA CAMD contacted Wood for information on Wood's experience with Nafion dryers at CASTNET ozone sites. Wood provided EPA with information on both field and QA aspects of the dryers for EPA's Office of Research and Development.

The VPI120, VA site was relocated during July 2020. The new site location is within 10 kilometers of the old location, so the site retained its CASTNET and NADP site identification numbers. However, the new location is at a different elevation with different terrain, which required the site to change its AQS ID number.

Review and updating of the CASTNET QAPP continued during third quarter. One of the updates included changing the P-flag criterion from 100 ppb to 130 ppb for nine western sites based on a 5-year average of the daily maximum 8-hour average ozone concentration. A list of the sites was included in the draft of the CASTNET QAPP Revision 9.4, which was submitted to EPA on November 1, 2020.

Quarterly/Annual Summary

Table 1 lists the quarters of data that were validated to Level 3 during 2020 by site calibration group. Table 2 lists the sites in each calibration group along with the usual semiannual, and in some cases, quarterly calibration schedule for each site. Due to the travel restrictions that resulted from the COVID-19 pandemic, sites were calibrated when travel was permitted, and calibration personnel were available. The EGB181, ON site, which is located in Canada, was subject to more extensive travel restrictions and went 13 months between calibrations. The sites in calibration group Eastern 2 (E-2), in the northeastern United States, were also located in areas with significant travel restrictions. The six-month calibration schedule for these sites was extended to about nine months.

Table 3 presents the measurement criteria for continuous field measurements. These criteria apply to the instrument challenges performed during site calibrations. Table 4 presents the measurement criteria for laboratory filter pack measurements. These criteria apply to the QC samples listed in the following section of this report. Table 5 presents the critical criteria for ozone monitoring. Table 6 presents the critical criteria for trace-level gas monitoring.

Laboratory Intercomparison Results Summary

Wood's CASTNET laboratory regularly participates in the ECCC Proficiency Testing (PT) Program for Inorganic Environmental Substances. The results reported by the participating laboratories are evaluated for systematic bias and precision. Systematic bias is assessed using the Youden (1969) non-parametric analysis, while precision is calculated using algorithm A from the ISO standard 13528 (ISO, 2005). Laboratory results are considered systematically biased when individual parameters are ranked by the Youden analysis to be consistently and significantly higher or lower than the assigned value without regard to flagged results. The CASTNET laboratory's proficiency testing plan requires action for individual test results that are greater than three standard deviations from the assigned value, bias 5 percent or higher for a single parameter, three or more biased results of any magnitude in a single study, or a consecutive study result indicating bias of any magnitude for a given parameter.

Usually, Wood participates in two ECCC PT studies each year. Due to the COVID-19 pandemic and associated restrictions, ECCC only offered one PT study during 2020. During March 2020, Wood received results for sample analyses submitted for PT study 0115 for Rain and Soft Waters to the National Laboratory of Environmental Testing, a branch of the National Water Research Institute with ECCC that provides QA services. All results passed with no flags. Analyses of all parameters were rated as "good" for PT study 0115 (ECCC, 2020).

Quality Control Analysis Count

The QC sample statistics presented in this report are for reference standards (RF) and continuing calibration verification spikes (CCV) used to assess accuracy and for replicate sample analyses (RP) used to assess "in-run" precision. In addition, laboratory method blanks (MB) containing reagents without a filter; laboratory blanks (LB) containing reagents and a new, unexposed filter; and field blanks (FB) containing reagents and an unexposed filter that was loaded into a filter pack assembly and shipped to and from the monitoring site while remaining in sealed packaging are also included. Tables 7 through 10 present the number of analyses in each category that were performed during each quarter of 2020.

Sample Receipt Statistics

Ninety-five percent of field samples from EPA-sponsored sites should be received by the CASTNET laboratory in Gainesville, FL no later than 14 days after removal from the sampling tower. Table 11 presents the relevant sample receipt statistics for each of the four quarters of 2020 together with an annual summary for each category. Due to issues arising from the pandemic and U.S. Postal Service policy decisions, mail delivery service was often delayed resulting in a 91 percent average for 2020. The annual average number of days to receipt for 2019 was 6.0 days. The annual average number of days to receipt for 2020 was 8.5 days.

Data Quality Indicator (DQI) Results

Figures 1 through 3 present the results of RF, CCV, and RP QC sample analyses for fourth quarter 2020. All results were within the criteria listed in Table 4. Table 12 presents the percent recoveries and standard deviations for RF, CCV, and RP QC sample analyses for 2020. Quarterly averages are all within criteria.

Table 13 presents quarterly co-located filter pack precision results for data validated to Level 3 during the year. During fourth quarter 2019, The MARPD values exceeded the 20 percent criterion at ROM406/206 for NO₃⁻. Unlike the MCK131/231 site, which is sponsored entirely by EPA, the ROM406 site is sponsored by NPS and the ROM206 site is sponsored by EPA. Different site operators are used for each of the co-located Rocky Mountain sites. The sampling on/off times at these sites differ by many hours due to differing site operator schedules. These samples showed on/off time differences varying from 5 to 10 hours. Sampling times for the samples with largest percent difference varied two hours for one site and four hours the other. Statistical comparisons of the Rocky Mountain sites were compounded by low sample concentrations. The fourth quarter 2019 average NO₃⁻ concentration for ROM406/206 was approximately three times the reporting limit. Results for MCK131/231, KY were within the criterion for all of the 11 parameters reported.

Figure 4 presents completeness statistics for continuous measurements validated to Level 3 during the year. Only five sites report the meteorological parameters included in Figure 4. Two of the five meteorological sites experienced significant damage during 2020. The BVL130, IL site was vandalized in early June 2020. The repairs were finalized in mid-June. The CHE185, OK site suffered a lightning strike in mid-April. Repairs were not finalized until early June because of shutdowns and restrictions in place due to the COVID-19 pandemic. As a result, sigma theta, wind direction, wind speed, and relative humidity averaged less than 90 percent completeness for 2020.

Table 14 presents summary statistics of critical criteria measurements at ozone sites collected during fourth quarter 2020. The statistics presented contain data validated at Level 2 and Level 3. All data associated with QC checks that fail to meet the criteria listed in Table 5 were or will be invalidated unless the cause of failure has no effect on ambient data collection, and passing results still meet frequency criteria. Results in shaded cells either exceed documented criteria or are otherwise notable. Table 15 presents observations associated with the shaded cell results in Table 14.

Table 16 presents summary statistics of critical criteria measurements at trace-level gas monitoring sites collected during fourth quarter 2020. The statistics presented contain data validated at Level 2

and Level 3. All data associated with QC checks that fail to meet the criteria listed in Table 6 were or will be invalidated unless the cause of failure has no effect on ambient data collection, and passing results still meet frequency criteria. Results in shaded cells either exceed documented criteria or are otherwise notable. Table 17 presents observations associated with the shaded cell results in Table 16.

Laboratory Control Sample Analysis

The laboratory control sample (LCS) is a reagent blank spiked with the target analytes from the established analytical methods and carried through the same extraction process that field samples must undergo. The LCS is not required by the CASTNET QA/QC program. LCS analyses are performed by the laboratory to monitor for potential sample handling artifacts and provide a means to identify possible analyte loss from extraction to extraction. Figure 5 presents LCS analysis results for fourth quarter 2020. All recovery values were between 92.9 percent and 106.5 percent.

Blank Results

Figures 6 through 8 present the results of MB, LB, and FB QC sample analyses for fourth quarter 2020. All fourth quarter results were within criteria (two times the reporting limit) listed in Table 4 with the exception of four potassium FB results. All of the FB exceeding the criterion were in the batch shipped for the May 26, 2020 sampling week. None of the associated field samples exhibited unusual measurements. Table 18 summarizes the record of filter blanks for 2020. All other blank QC checks in their respective batches were within criteria.

Suspect/Invalid Filter Pack Samples

Filter pack samples that were flagged as suspect or invalid during each of the four quarters of 2020 are listed in Table 19. This table also includes associated site identification and a brief description of the reason the sample was flagged. During fourth quarter, 13 filter pack samples were invalidated.

Field Problem Count

Table 20 presents counts of field problems affecting continuous data collection for more than one day for each quarter during 2020. The problem counts are sorted by a 30-, 60-, or 90-day period to resolution. A category for unresolved problems is also included. Time to resolution indicates the period taken to implement corrective action.

Field Calibration Results

A summary of field calibration failures by parameter for each quarter of 2020 is listed in Table 21. Calibrations were performed at 15 sites during fourth quarter 2020. During 2020, all sites and parameters were within the criteria listed in Table 3 with the exception of the parameters at the eight sites that are listed in Table 21.

Table 22 presents field accuracy results for 2020 based on instrument challenges performed using independent reference standards during site calibration visits. Each parameter was within its criterion with at least 90 percent frequency except delta temperature (ambient) at 87.5 percent and solar radiation at 85.7 percent frequency. Per CASTNET project protocols, data are flagged but still considered valid if the calibration criterion is not exceeded by more than its magnitude (i.e., if within

two times the criterion). All calibration failures reported in 2020 for the indicated parameters were within two times the criterion.

References

- American Society for Testing and Materials (ASTM). 2008. ASTM E29-08, "Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications." ASTM International, West Conshohocken, PA, DOI:10.1520/E0029-08. www.astm.org.
- Environment and Climate Change Canada (ECCC) Water Science and Technology Directorate. 2020. Rain and Soft Waters PT Study 0115 Report. Proficiency Testing Program, Burlington, Ontario, Canada. Prepared for Wood Environment and Infrastructure, Inc., Newberry, FL, USA.
- International Organization for Standardization (ISO). 2005. *Statistical Methods for the Use in Proficiency Testing by Interlaboratory Comparisons, Annex C, Robust Analysis, Section C.1: Algorithm A*. Standard 13528. ISO 13528:2005(E).
- U.S. Environmental Protection Agency (EPA). 2017. Title 40 *Code of Federal Regulations* Part 58, "Appendix A to Part 58 – Quality Assurance Requirements for Monitors used in Evaluations of National Ambient Air Quality Standards."
- Wood Environment & Infrastructure Solutions, Inc. (Wood) 2020. *Clean Air Status and Trends Network (CASTNET) Quality Assurance Project Plan (QAPP) Revision 9.3*. Prepared for U.S. Environmental Protection Agency (EPA), Office of Air and Radiation, Clean Air Markets Division, Washington, DC. Contract No. EP-W-16-015. Gainesville, FL. <https://java.epa.gov/castnet/documents.do>.
- Youden, W.J. (Ku, H.H., ed). 1969. *Precision Measurement and Calibration*. NBS Special Publication 300-Volume 1. U.S. Government Printing Office, Washington, DC.

Table 1 Data Validated to Level 3 through Fourth Quarter 2020

Calibration Group*	Months Available	Number of Months	Complete Quarters	Number of Quarters
SE-4/MW-6 [†]	July 2019 – June 2020	12	Quarter 3 2019 – Quarter 2 2020	4
E-1/SE-5	August 2019 – July 2020	12	Quarter 4 2019 – Quarter 2 2020	3
MW-7/W-9	September 2019 – August 2020	12	Quarter 4 2019 – Quarter 2 2020	3
E-2/MW-8	October 2019 – September 2020	12	Quarter 4 2019 – Quarter 3 2020	4
E-3/W-10 [‡]	May 2019 – April 2020	12	Quarter 3 2019 – Quarter 1 2020	3

Notes: * The sites contained in each calibration group are listed in Table 2.

[†] Contains MCK131/231 co-located pair

[‡] Contains ROM206 of the ROM406/ROM206 co-located pair

Table 2 Field Calibration Schedule for 2020

Calibration Group	Months Calibrated	Sites Calibrated			
Eastern Sites (22 Total)					
E-1 (8 Sites)	February/August	BEL116, MD BWR139, MD	WSP144, NJ CTH110, NY	ARE 128, PA PSU106, PA	PED108, VA VPI120, VA
E-2 (9 Sites)	April/October	ABT147, CT ASH135, ME	WST109, NH CAT175, NY	HWF187, NY ¹ NIC001, NY	WFM105, NY EGB181, ON UND002, VT
E-3 (5 Sites)	May/November	KEF112, PA MKG113, PA	LRL117, PA PAR107, WV	CDR119, WV	
Southeastern Sites (11 Total)					
SE-4 (6 Sites)	January/July	SND152, AL GAS153, GA	BFT142, NC CND125, NC	COW137, NC SPD111, TN	
SE-5 (5 Sites)	February/August	CAD150, AR IRL141, FL	SUM156, FL CVL151, MS	DUK008, NC ²	
Midwestern Sites (19 Total)					
MW-6 (6 Sites)	January/July	CDZ171, KY CKT136, KY	MCK131, KY MCK231, KY	PNF126, NC ¹ ESP127, TN	
MW-7 (9 Sites)	March/September	ALH157, IL BVL130, IL ³	STK138, IL VIN140, IN	RED004, MN DCP114, OH	OXF122, OH PRK134, WI QAK172, OH
MW-8 (4 Sites)	April/October	SAL133, IN HOX148, MI	ANA115, MI UVL124, MI		
Western Sites (11 Total)					
W-9 (5 Sites)	March/September	KNZ184, KS KIC003, KS	CHE185, OK SAN189, NE	ALC188, TX	
W-10 (6 Sites)	May/November	GTH161, CO ROM206, CO ²	NPT006, ID CNT169, WY	PND165, WY ² PAL190, TX	

Notes: ¹ Trace-level gas calibrations are performed quarterly in January, April, July, and October.

² Trace-level gas calibrations are performed quarterly in February, May, August, and November.

³ Trace-level gas calibrations are performed quarterly in March, June, September, and December.

Table 3 Data Quality Indicators for CASTNET Continuous Measurements

Measurement		Criteria ¹	
Parameter ²	Method	Precision	Accuracy
Filter pack flow	Mass flow controller	± 10%	± 5%
Ozone ³	UV absorbance	All points within ± 2% of full scale of best fit straight line Linearity error < 5%	
Wind speed	Anemometer	± 0.5 m/s	The greater of ± 0.5 m/s for winds < 5 m/s or ± 5% for winds ≥ 5 m/s
Wind direction	Wind vane	± 5°	± 5°
Sigma theta	Wind vane	Undefined	Undefined
Ambient temperature	Platinum RTD	± 1.0°C	± 0.5°C
Delta temperature	Platinum RTD	± 0.5°C	± 0.5°C
Relative humidity	Thin film capacitor	± 10% (of full scale)	± 10%
Precipitation	Tipping bucket rain gauge	± 10% (of reading)	± 0.05 inch ⁴
Solar radiation	Pyranometer	± 10% (of reading taken at local noon)	± 10%
Surface wetness	Conductivity bridge	Undefined	Undefined

Notes: °C = degrees Celsius
m/s = meters per second
RTD = resistance-temperature device
UV = ultraviolet

¹Precision criteria apply to co-located instruments, and accuracy criteria apply to calibration of instruments. Co-located precision criteria do not apply to CASTNET sites that are configured and operated in accordance with Part 58 of Title 40 of the *Code of Federal Regulations* (EPA, 2017)

²Meteorological parameters are only measured at five of the EPA-sponsored CASTNET sites: IRL141, FL; BVL130, IL; BEL116, MD; CHE185, OK; and PND165, WY.

³Ozone is not measured at eight EPA-sponsored CASTNET sites: KIC003, KS; KNZ184, KS; RED004, MN; EGB181, ON; CAT175, NY; NIC001, NY; WFM105, NY; and UND002, VT.

⁴For target value of 0.50 inch

Table 4 Data Quality Indicators for CASTNET Laboratory Measurements

Analyte	Method	Precision ¹ (MARPD)	Accuracy ² (%)	Nominal Reporting Limits	
				mg/L	µg/Filter
Ammonium (NH ₄ ⁺)	AC	20	90–110	0.020*	0.5
Sodium (Na ⁺)	ICP-OES	20	95–105	0.005	0.125
Potassium (K ⁺)	ICP-OES	20	95–105	0.006	0.15
Magnesium (Mg ²⁺)	ICP-OES	20	95–105	0.003	0.075
Calcium (Ca ²⁺)	ICP-OES	20	95–105	0.006	0.15
Chloride (Cl ⁻)	IC	20	95–105	0.020	0.5
Nitrate (NO ₃ ⁻)	IC	20	95–105	0.008*	0.2
Sulfate (SO ₄ ²⁻)	IC	20	95–105	0.040	1.0

Notes: ¹ This column lists precision goals for both network precision calculated from co-located filter samples and laboratory precision based on replicate samples for samples > five times the reporting limit. The criterion is ± the reporting limit if the sample is ≤ five times the reporting limit.

² This column lists laboratory accuracy goals based on reference standards and continuing calibration verification spikes. The criterion is 90–110 percent for ICP-OES reference standards.

AC = automated colorimetry
 IC = ion chromatography
 ICP-OES = inductively coupled plasma-optical emission spectrometry
 MARPD = mean absolute relative percent difference
 mg/L = milligrams per liter
 µg/Filter = micrograms per filter
 * = as nitrogen

Values are rounded according to American Society for Testing and Materials (ASTM) E29-08, "Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications" (ASTM, 2008).

For more information on analytical methods and associated precision and accuracy criteria, see the CASTNET QAPP, (Wood, 2020).

Table 5 Ozone Critical Criteria*

Type of Check	Analyzer Response
Zero	Less than ± 3.1 parts per billion (ppb)
Span	Less than ± 7.1 percent between supplied and observed concentrations
Single Point QC	Less than ± 7.1 percent between supplied and observed concentrations

Notes: * Applies to CASTNET sites that are configured and operated in accordance with Part 58 of Title 40 of the *Code of Federal Regulations* (EPA, 2017). The minimum frequency for these checks is once every two weeks.

Values are rounded according to ASTM E29-08, "Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications" (ASTM, 2008).

Table 6 Trace-level Gas Monitoring Critical Criteria *

Parameter	Analyzer Response	
	Zero Check	Span Check / Single Point QC Check
SO ₂	Less than ± 1.51 ppb	Less than ± 10.1 percent between supplied and observed concentrations
NO _y	Less than ± 1.51 ppb	
CO	Less than ± 30.1 ppb	

Notes: *Applies to CASTNET sites that are configured and operated in accordance with Part 58 of Title 40 of the *Code of Federal Regulations* (EPA, 2017). The minimum frequency for these checks is once every two weeks.

Values are rounded according to ASTM E29-08, “Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications” (ASTM, 2008).

SO₂ = sulfur dioxide

NO_y = total reactive oxides of nitrogen

CO = carbon monoxide

ppb = parts per billion

Table 7 QC Analysis Count for First Quarter 2020

Filter Type	Parameter	RF Sample Count	CCV Sample Count	RP Sample Count	MB Sample Count	LB Sample Count	FB Sample Count
Teflon	SO ₄ ²⁻	75	211	89	18	28	93
	NO ₃ ⁻	75	211	89	18	28	93
	NH ₄ ⁺	36	184	86	18	26	93
	Cl ⁻	75	211	89	18	28	93
	Ca ²⁺	36	185	86	18	26	93
	Mg ²⁺	36	185	86	18	26	93
	Na ⁺	36	185	86	18	26	93
	K ⁺	36	185	86	18	26	93
Nylon	SO ₄ ²⁻	60	214	90	18	28	93
	NO ₃ ⁻	60	214	90	18	28	93
Cellulose	SO ₄ ²⁻	51	184	84	17	26	93

Table 8 QC Analysis Count for Second Quarter 2020

Filter Type	Parameter	RF Sample Count	CCV Sample Count	RP Sample Count	MB Sample Count	LB Sample Count	FB Sample Count
Teflon	SO ₄ ²⁻	67	192	81	17	26	92
	NO ₃ ⁻	67	192	81	17	26	92
	NH ₄ ⁺	34	176	81	17	26	92
	Cl ⁻	67	192	81	17	26	92
	Ca ²⁺	34	177	81	17	26	92
	Mg ²⁺	34	177	81	17	26	92
	Na ⁺	34	177	81	17	26	92
	K ⁺	34	177	81	17	26	92
Nylon	SO ₄ ²⁻	46	183	78	16	24	92
	NO ₃ ⁻	46	183	78	16	24	92
Cellulose	SO ₄ ²⁻	47	171	78	16	26	92

Table 9 QC Analysis Count for Third Quarter 2020

Filter Type	Parameter	RF Sample Count	CCV Sample Count	RP Sample Count	MB Sample Count	LB Sample Count	FB Sample Count
Teflon	SO ₄ ²⁻	68	197	81	18	26	92
	NO ₃ ⁻	68	197	81	18	26	92
	NH ₄ ⁺	34	179	81	17	26	92
	Cl ⁻	68	197	81	18	26	92
	Ca ²⁺	34	180	81	17	26	92
	Mg ²⁺	34	180	81	17	26	92
	Na ⁺	34	180	81	17	26	92
	K ⁺	34	180	81	17	26	92
Nylon	SO ₄ ²⁻	49	188	78	16	26	92
	NO ₃ ⁻	49	188	78	16	26	92
Cellulose	SO ₄ ²⁻	47	172	79	16	26	92

Table 10 QC Analysis Count for Fourth Quarter 2020

Filter Type	Parameter	RF Sample Count	CCV Sample Count	RP Sample Count	MB Sample Count	LB Sample Count	FB Sample Count
Teflon	SO ₄ ²⁻	67	180	75	17	22	77
	NO ₃ ⁻	67	180	75	17	22	77
	NH ₄ ⁺	32	161	74	16	22	77
	Cl ⁻	67	180	75	17	22	77
	Ca ²⁺	32	165	74	16	22	77
	Mg ²⁺	32	165	74	16	22	77
	Na ⁺	32	165	74	16	22	77
	K ⁺	32	165	74	16	22	77
Nylon	SO ₄ ²⁻	48	184	77	17	22	77
	NO ₃ ⁻	48	184	77	17	22	77
Cellulose	SO ₄ ²⁻	44	154	69	16	22	77

Table 11 Filter Pack Receipt Summary for 2020

Description	First Quarter	Second Quarter	Third Quarter	Fourth Quarter	Annual Summary
Count of samples received more than 14 days after removal from tower:	17	33	88	121	259
Count of all samples received:	820	662	730	673	2885
Fraction of samples received within 14 days:	0.979	0.950	0.879	0.820	0.910
Average interval in days:	6.937	7.285	9.359	10.247	8.457*
First receipt date:	01-03-2020	04-01-2020	07-01-2020	10-01-2020	01-03-2020
Last receipt date:	03-31-2020	06-16-2020	09-18-2020	12-28-2020	12-28-2020

Note: Sample shipments for the Egbert, Ontario site (EGB181) are in groups of four. Samples associated with EGB181 are excluded from this statistic.

*annual average

Table 12 Filter Pack QC Summary for 2020

Filter Type	Parameter	Reference Sample ¹ Recovery (%R)			Continuing Calibration Verification Samples (%R)			In-Run Replicate ² (RPD)		
		Mean	Std. Dev.	Count ³	Mean	Std. Dev.	Count ³	Mean	Std. Dev.	Count ³
Teflon	SO ₄ ²⁻	100.68	1.72	277	101.16	0.99	780	1.25	1.22	326
	NO ₃ ⁻	101.80	1.24	277	99.16	0.95	780	1.83	1.83	326
	NH ₄ ⁺	100.01	1.49	136	100.24	1.42	700	0.63	0.75	322
	Ca ²⁺	99.78	2.14	136	100.58	1.02	707	1.58	2.79	322
	Mg ²⁺	99.59	1.31	136	99.93	0.81	707	1.83	2.18	322
	Na ⁺	96.95	1.28	136	99.91	0.94	707	1.31	1.86	322
	K ⁺	97.56	2.55	136	99.88	0.76	707	1.92	2.03	322
	Cl ⁻	100.56	1.51	277	102.77	0.88	780	2.07	1.82	326
Nylon	SO ₄ ²⁻	101.92	1.28	203	101.00	1.39	769	4.69	3.74	323
	NO ₃ ⁻	101.66	1.43	203	98.81	1.58	769	1.89	2.28	323
Cellulose	SO ₄ ²⁻	102.15	0.89	189	101.43	0.73	681	1.75	1.93	310

Notes: % R = percent recovery
RPD = relative percent difference

¹Results of reference sample analyses provide accuracy estimates

²Results of replicate analyses provide precision estimates

³Number of QC Samples

Table 13 Precision Results for Third Quarter 2016 through Second Quarter 2020

Quarter	SO ₄ ²⁻	NO ₃	NH ₄ ⁺	Ca ²⁺	Mg ²⁺	Na ⁺	K ⁺	Cl ⁻	HNO ₃	SO ₂	Total NO ₃
MCK131/231, KY											
2019 Q3	1.96	6.84	1.84	2.89	4.01	2.38	3.01	0.95	3.48	7.29	3.71
2019 Q4	2.87	3.53	2.21	4.47	5.24	5.11	8.04	4.37	4.08	2.84	1.79
2020 Q1	2.90	3.53	3.24	4.98	6.11	2.61	2.87	4.30	4.44	4.82	2.70
2020 Q2	2.75	6.86	2.06	5.87	5.16	5.09	6.01	1.06	4.36	5.71	2.54
Average	2.62	5.19	2.34	4.55	5.13	3.80	4.98	2.67	4.09	5.17	2.69
ROM406/206, CO											
2019 Q3	4.07	10.80	6.04	3.93	4.66	5.88	7.18	2.79	4.20	9.36	4.11
2019 Q4	3.50	27.98	9.03	11.29	9.97	9.61	12.29	7.32	10.22	9.57	11.08
2020 Q1	4.66	17.60	7.51	6.27	11.62	15.96	12.11	16.85	12.53	11.35	3.12
2020 Q2	4.02	11.23	5.66	5.95	9.15	10.90	10.83	10.00	8.42	9.57	5.66
Average	4.06	16.90	7.06	6.86	8.85	10.59	10.60	9.24	8.84	9.96	5.99

Table 14 Ozone QC Summary for Fourth Quarter 2020 (1 of 2)

Site ID	% Span Pass ¹	Span %D ²	% Single Point QC Pass ¹	Single Point QC %D ²	% Zero Pass ¹	Zero Average (ppb) ²
ABT147, CT	100.00	1.43	100.00	1.44	100.00	0.19
ALC188, TX	97.85	3.34	98.91	2.74	100.00	0.33
ALH157, IL	95.74	4.36	95.74	3.93	95.74	0.82
ANA115, MI	100.00	0.74	100.00	1.48	100.00	0.12
ARE128, PA	100.00	1.04	100.00	1.08	100.00	0.09
ASH135, ME	98.92	1.59	100.00	0.58	100.00	0.22
BEL116, MD	100.00	0.61	100.00	0.92	100.00	0.41
BFT142, NC	100.00	1.54	100.00	1.31	98.94	0.59
BVL130, IL	100.00	0.90	100.00	0.75	100.00	0.12
BWR139, MD	100.00	1.23	100.00	1.25	100.00	0.74
CAD150, AR	100.00	0.97	100.00	1.53	100.00	0.37
CDR119, WV	100.00	1.43	100.00	1.29	100.00	0.21
CDZ171, KY	100.00	1.14	100.00	1.40	100.00	0.23
CKT136, KY	100.00	0.95	100.00	1.02	100.00	0.13
CND125, NC	100.00	1.69	100.00	1.09	100.00	0.79
CNT169, WY	100.00	0.68	100.00	0.69	100.00	0.21
COW137, NC	100.00	0.66	100.00	1.28	100.00	0.46
CTH110, NY	100.00	3.52	100.00	3.80	100.00	0.14
CVL151, MS	100.00	0.74	100.00	0.82	100.00	0.37
DCP114, OH	76.09	18.27	75.00	17.22	83.33	1.44
ESP127, TN	99.01	1.11	99.01	0.74	100.00	0.30

Table 14 Ozone QC Summary for Fourth Quarter 2020 (2 of 2)

Site ID	% Span Pass ¹	Span %D ²	% Single Point QC Pass ¹	Single Point QC %D ²	% Zero Pass ¹	Zero Average (ppb) ²
GAS153, GA	93.00	2.56	100.00	1.85	100.00	0.50
GTH161, CO	100.00	1.16	100.00	1.29	100.00	0.17
HOX148, MI	97.70	1.47	98.84	1.26	97.59	0.40
HWF187, NY	100.00	2.48	98.92	2.32	98.92	0.26
IRL141, FL	100.00	0.50	94.05	2.82	92.86	2.12
KEF112, PA	100.00	0.79	100.00	0.80	100.00	0.14
LRL117, PA	100.00	0.49	100.00	0.67	100.00	0.25
MCK131, KY	100.00	0.62	100.00	0.69	100.00	0.18
MCK231, KY	100.00	0.46	100.00	0.60	100.00	0.17
MKG113, KY	100.00	2.80	100.00	2.33	100.00	0.24
NPT006, ID	100.00	1.83	100.00	2.38	100.00	0.20
OXF122, OH	100.00	1.06	100.00	1.21	100.00	0.23
PAL190, TX	100.00	1.25	100.00	0.66	100.00	0.32
PAR107, WV	100.00	0.60	100.00	0.78	100.00	0.29
PED108, VA	100.00	1.85	100.00	1.85	100.00	0.37
PND165, WY	100.00	0.92	100.00	1.38	100.00	0.17
PNF126, NC	100.00	0.34	100.00	0.84	100.00	0.27
PRK134, WI	100.00	0.71	100.00	0.62	100.00	0.12
PSU106, PA	100.00	0.32	100.00	0.68	100.00	0.19
QAK172, OH	100.00	1.33	100.00	1.82	100.00	0.39
ROM206, CO	100.00	2.78	100.00	2.82	100.00	0.22
SAL133, IN	100.00	0.65	100.00	0.66	100.00	0.21
SAN189, NE	100.00	0.84	100.00	1.22	100.00	0.30
SND152, AL	96.04	4.14	96.04	3.53	96.00	1.39
SPD111, TN	100.00	0.70	100.00	0.98	100.00	0.19
STK138, IL	100.00	0.45	100.00	0.50	100.00	0.22
SUM156, FL	100.00	3.32	100.00	2.58	100.00	0.20
UMA009, WA	100.00	1.71	100.00	1.45	100.00	0.53
UVL124, MI	100.00	0.69	100.00	1.18	100.00	0.15
VIN140, IN	100.00	0.55	100.00	0.63	100.00	0.16
VPI120, VA	98.90	2.73	100.00	1.67	100.00	0.16
WSP144, NJ	100.00	0.93	100.00	0.93	100.00	0.20
WST109, NH	100.00	0.41	100.00	0.83	98.95	0.40

Notes: ¹Percentage of comparisons that pass the criteria listed in Table 5. Values falling below 90 percent are addressed in Table 15.

²Absolute value of the average percent differences between the on-site transfer standard and the site monitor. Values exceeding the criteria listed in Table 5 are addressed in Table 15.

%D = percent difference

ppb = parts per billion

Table 15 Ozone QC Observations for Fourth Quarter 2020

Site ID	QC Criterion	Comments
DCP114, OH	% Span Pass Span %D % Single Point QC Pass Single Point QC %D % Zero Pass	There was a leak in the sample line in November 2020.

Note: %D = percent difference

Table 16 Trace-level Gas QC Summary for Fourth Quarter 2020

Parameter	% Span Pass ¹	Span %D ²	% Single Point QC Pass ¹	Single Point QC %D ²	% Zero Pass ¹	Zero Average (ppb) ²
BVL130, IL						
SO ₂	100.00	2.38	100.00	2.82	100.00	0.32
NO _y	100.00	1.57	100.00	1.26	100.00	0.50
CO	94.29	3.41	80.00	17.52	77.14	49.11
DUK008, NC						
NO _y	95.35	7.91	95.35	7.88	100.00	0.14
HWF187, NY						
NO _y	100.00	3.31	100.00	4.89	97.62	0.28
PND165, WY						
NO _y	97.92	3.74	95.83	5.25	100.00	0.34
PNF126, NC						
NO _y	96.00	3.07	100.00	4.60	100.00	0.28
ROM206, CO						
NO _y	95.56	5.77	93.33	7.39	100.00	0.32

Notes: ¹Percentage of comparisons that pass the criteria listed in Table 6. Values falling below 90 percent are addressed in Table 17.

²Absolute value of the average percent differences between the supplied and observed concentrations. Values exceeding the criteria listed in Table 6 are addressed in Table 17.

%D = percent difference

ppb = parts per billion

Table 17 Trace-level Gas QC Observations for Fourth Quarter 2020

Site ID	Parameter	QC Criterion	Comments
BVL130, IL	CO	% Single Point QC Pass Single Point QC %D % Zero Pass Zero Average	The analyzer malfunctioned in December. The CO source was replaced in January 2021.

Notes: %D = percent difference

Table 18 Summary of Filter Blanks for 2020 (1 of 2)

Parameter Name	Detection Limit Total μg	Total Number	Number > Detection Limit	Average Total μg	Average Absolute Deviation	Maximum Total μg
FIELD BLANKS						
Teflon-NH ₄ ⁺ -N	0.500	320	0	0.500	0.000	0.500
Teflon- NO ₃ ⁻ -N	0.200	320	0	0.200	0.000	0.200
Teflon- SO ₄ ²⁻	1.000	320	0	1.000	0.000	1.000
Cl ⁻	0.500	320	0	0.500	0.000	0.500
Ca ²⁺	0.150	320	0	0.150	0.000	0.150
Mg ²⁺	0.075	320	0	0.075	0.000	0.075
Na ⁺	0.125	320	0	0.125	0.000	0.125
K ⁺	0.150	320	11	0.158	0.015	1.382
Nylon- NO ₃ ⁻ -N	0.200	320	3	0.200	0.001	0.248
Nylon - SO ₄ ²⁻	1.000	320	0	1.000	0.000	1.000
Cellulose - SO ₄ ²⁻	2.000	320	14	2.027	0.051	3.340
LABORATORY BLANKS						
Teflon-NH ₄ ⁺ -N	0.500	94	0	0.500	0.000	0.500
Teflon- NO ₃ ⁻ -N	0.200	96	0	0.200	0.000	0.200
Teflon- SO ₄ ²⁻	1.000	96	0	1.000	0.000	1.000
Cl ⁻	0.500	96	0	0.500	0.000	0.500
Ca ²⁺	0.150	94	0	0.150	0.000	0.150
Mg ²⁺	0.075	94	0	0.075	0.000	0.075
Na ⁺	0.125	94	1	0.125	0.001	0.150
K ⁺	0.150	94	1	0.151	0.001	0.215
Nylon- NO ₃ ⁻ -N	0.200	96	4	0.201	0.002	0.255
Nylon -SO ₄ ²⁻	1.000	96	0	1.000	0.000	1.000
Cellulose -SO ₄ ²⁻	2.000	94	0	2.000	0.000	2.000
METHOD BLANKS						
Teflon-NH ₄ ⁺ -N	0.500	62	0	0.500	0.000	0.500
Teflon- NO ₃ ⁻ -N	0.200	63	0	0.200	0.000	0.200
Teflon- SO ₄ ²⁻	1.000	63	0	1.000	0.000	1.000
Cl ⁻	0.500	63	0	0.500	0.000	0.500
Ca ²⁺	0.150	62	0	0.150	0.000	0.150
Mg ²⁺	0.075	62	0	0.075	0.000	0.075
Na ⁺	0.125	62	0	0.125	0.000	0.125
K ⁺	0.150	62	0	0.150	0.000	0.150
Nylon- NO ₃ ⁻ -N	0.200	61	0	0.200	0.000	0.200
Nylon -SO ₄ ²⁻	1.000	61	0	1.000	0.000	1.000
Cellulose -SO ₄ ²⁻	2.000	60	0	2.000	0.000	2.000

Table 18 Summary of Filter Blanks for 2020 (2 of 2)

Parameter Name	Detection Limit Total µg	Total Number	Number > Detection Limit	Average Total µg	Average Absolute Deviation	Maximum Total µg
ACCEPTANCE TEST VALUES ¹						
Teflon-NH ₄ ⁺ -N	0.500	216	0	0.500	0.000	0.500
Teflon- NO ₃ ⁻ -N	0.200	216	0	0.200	0.000	0.200
Teflon- SO ₄ ²⁻	1.000	216	0	1.000	0.000	1.000
Cl ⁻	0.500	216	0	0.500	0.000	0.500
Ca ²⁺	0.150	216	0	0.150	0.000	0.150
Mg ²⁺	0.075	216	0	0.075	0.000	0.075
Na ⁺	0.125	216	0	0.125	0.000	0.125
K ⁺	0.150	216	0	0.150	0.000	0.150
Nylon- NO ₃ ⁻ -N	0.200	300	0	0.200	0.000	0.200
Nylon -SO ₄ ²⁻	1.000	300	0	1.000	0.000	1.000
Cellulose -SO ₄ ²⁻	2.000	216	0	2.000	0.000	2.000

Note: ¹Only filter batches passing QC requirements are used for sampling and analysis.

Table 19 Filter Packs Flagged as Suspect or Invalid (1 of 2)

Site ID	Sample	Reason
First Quarter 2020		
BEL116, MD	2007001-06	Insufficient flow volume was due to a power failure.
BVL130, IL	2005001-08	Calibration flags were left in place. Data may be recovered.
CAT175, NY	2002001-11	Insufficient flow volume was due to a power failure.
ESP127, TN	2007001-23	Insufficient flow volume was due to a power failure.
FOR605, WY	2005005-03	Possible polling issue: flow data were null.
JOT403, CA	2005003-12	Possible polling issue: flow data were null.
NEC602, WY	2004005-04 2005005-04	The mass flow controller malfunctioned resulting in invalid flow rates for these samples.
NPT006, ID	2004004-04	Insufficient flow volume was due to a power failure.
Second Quarter 2020		
ACA416, ME	2015003-01	The power failed affected one week of sampling.
CVL151, MS	2015001-19 2023001-19	A power failure affected two weeks of sampling. A power failure affected one week of sampling.
FOR605, WY	2018005-03	A polling issue caused missing data. Data may be recovered during review and validation.
JOT403, CA	2018003-12	A polling issue caused missing data. Data may be recovered during review and validation.

Table 19 Filter Packs Flagged as Suspect or Invalid (2 of 2)

Site ID	Sample	Reason
Third Quarter 2020		
ABT147, CT	2032001-01	The site experienced an extended power outage.
BWR139, MD	2030001-09	The Teflon filter was perforated.
CDR119, WV	2029001-12	The mass flow controller (MFC) malfunctioned and was replaced.
CHE185, OK	2034004-02	The MFC malfunctioned and was replaced.
CTH110, NY	2030001-18	The cause of the problem is under investigation.
FOR605, WY	2031005-03	Flow data are missing.
JOT403, CA	2031003-12	Flow data are missing.
PSU106, PA	2031001-43	The sample was invalidated for suspect data.
SHE604, WY	2035005-05	Flow data are missing.
SPD111, TN	2036001-48	The site experienced a power outage.
UND002, VT	2033001-51 2034001-51	The site experienced an extended power outage.
Fourth Quarter 2020		
BEL116, MD	2044001-06 2045001-06	The site experienced an extended power outage.
BFT142, NC	2043001-07	The potassium value was invalidated as suspect.
BUF603, WY	2041005-02	The site experienced a power outage.
CDR119, WV	2042001-12	There were communication issues.
CNT169, WY	2043001-16 2044001-16	The data logger program froze and required reinstallation.
FOR605, WY	2044005-03	The site had a data transfer issue. Data are likely recoverable.
IRL141, FL	2042001-28	The mass flow controller failed and was replaced.
JOT403, CA	2044003-12	The site had a data transfer issue that is likely recoverable.
LAV410, CA	2042003-13 2043003-13	Power was off from 10/15/2020 to 10/27/2020.
QAK172, OH	2042001-44	Data were invalidated as suspect.

Table 20 Field Problems Affecting Data Collection

Days to Resolution	Problem Count
First Quarter 2020	
30	308
60	13
90	0
Unresolved by End of Quarter	15
Second Quarter 2020	
30	167
60	0
90	0
Unresolved by End of Quarter	28
Third Quarter 2020	
30	481
60	14
90	3
Unresolved by End of Quarter	2
Fourth Quarter 2020	
30	336
60	10
90	0
Unresolved by Date of Publication	19

Table 21 Field Calibration Failures by Parameter for 2020

Site ID	Parameter(s)
First Quarter 2020	
WSP144, NJ	Flow Rate
Second Quarter 2020	
	none
Third Quarter 2020	
ABT147, CT	Flow rate
BEL116, MD	Delta temperature
CHE185, OK	Flow rate
CVL151, MS	Temperature
IRL141, FL	Temperature, delta temperature
KIC003, KS	Temperature
Fourth Quarter 2020	
CDR119, WV	Flow rate

Note: Per CASTNET project protocols, data for all parameters except flow are flagged as “suspect” (S) but still considered valid if the calibration criterion is not exceeded by more than its magnitude (i.e., if within two times the criterion). If flow calibrations fall within two times the criterion, these data are adjusted per approved protocol described in the CASTNET QAPP, (Wood, 2020). Please refer to Table 15 for documentation of the QC failures affecting the validity of ozone data.

Table 22 Accuracy Results for 2020 Field Measurements

Parameter	Percent Within Criterion
Flow Rate	96.6
Wind Speed < 5 m/s	100.0
Wind Speed ≥ 5 m/s	100.0
Wind Direction North	100.0
Wind Direction South	100.0
Temperature (0°C)	97.4
Temperature (ambient)	97.4
Delta Temperature (0°C)	87.5*
Delta Temperature (ambient)	87.5*
Relative Humidity	100.0
Precipitation	100.0
Solar Radiation	100.0
Wetness (w/in 0.5 volts)	100.0

Notes: °C = degrees Celsius

m/s = meters per second

* = Per CASTNET project protocols, data are flagged as “suspect” (S) but still considered valid if the calibration criterion is not exceeded by more than its magnitude (i.e., if within two times the criterion). All calibration failures reported in 2020 for the indicated parameters were within two times the criterion.

Figure 1 Reference Standard Results for Fourth Quarter 2020 (percent recovery)

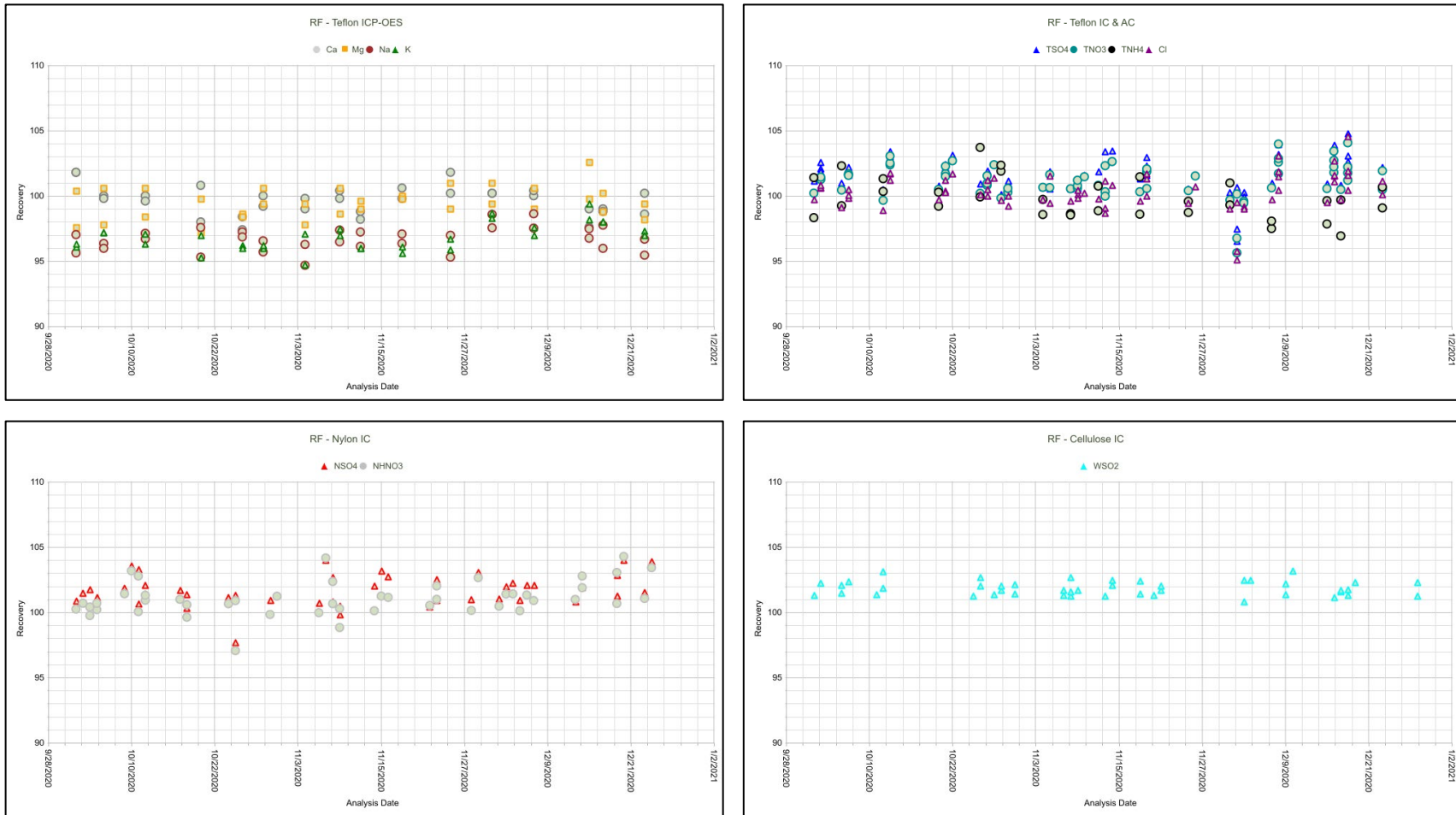


Figure 2 Continuing Calibration Spike Results for Fourth Quarter 2020 (percent recovery)

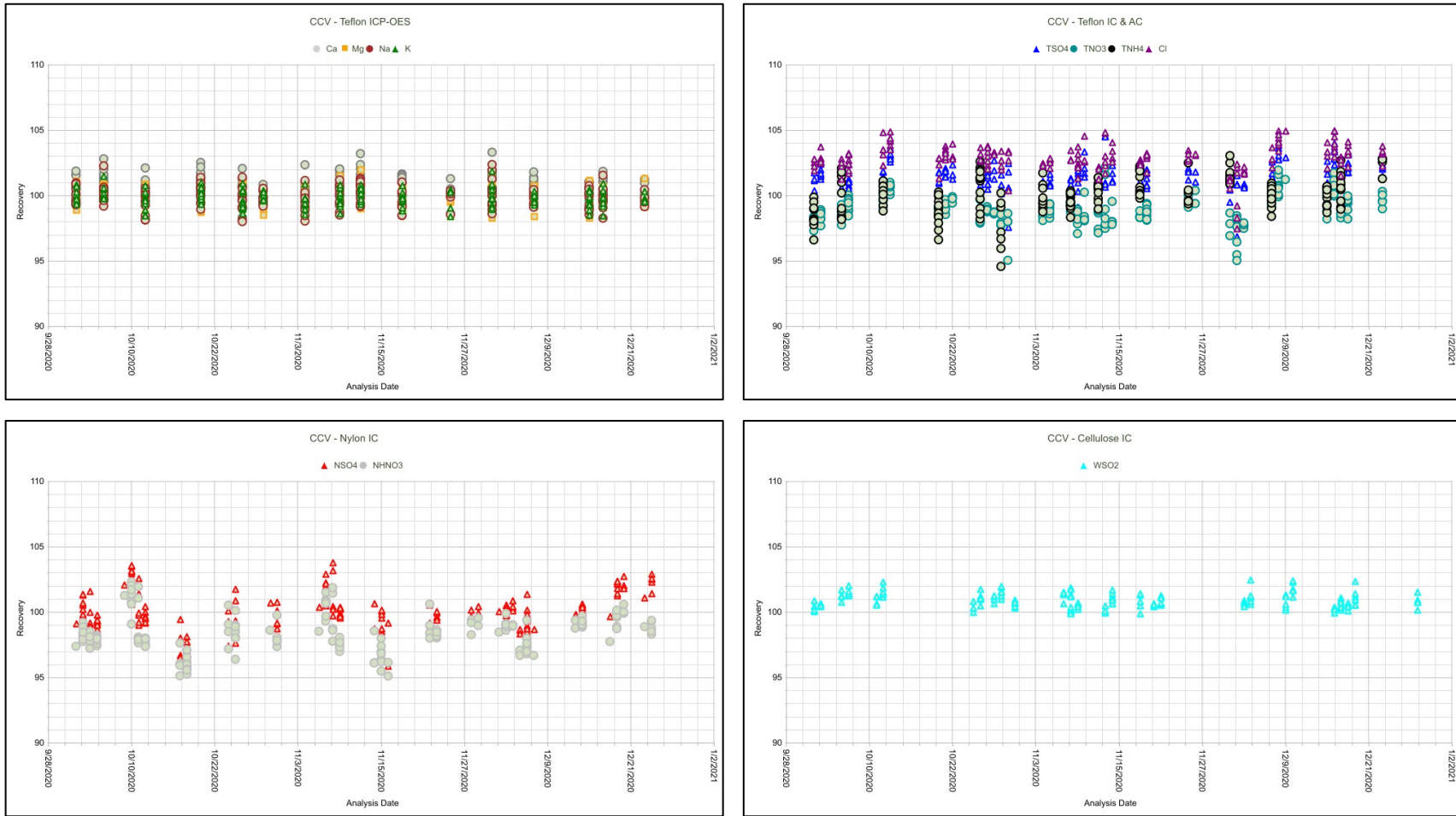


Figure 3 Replicate Sample Analysis Results for Fourth Quarter 2020 (percent difference)

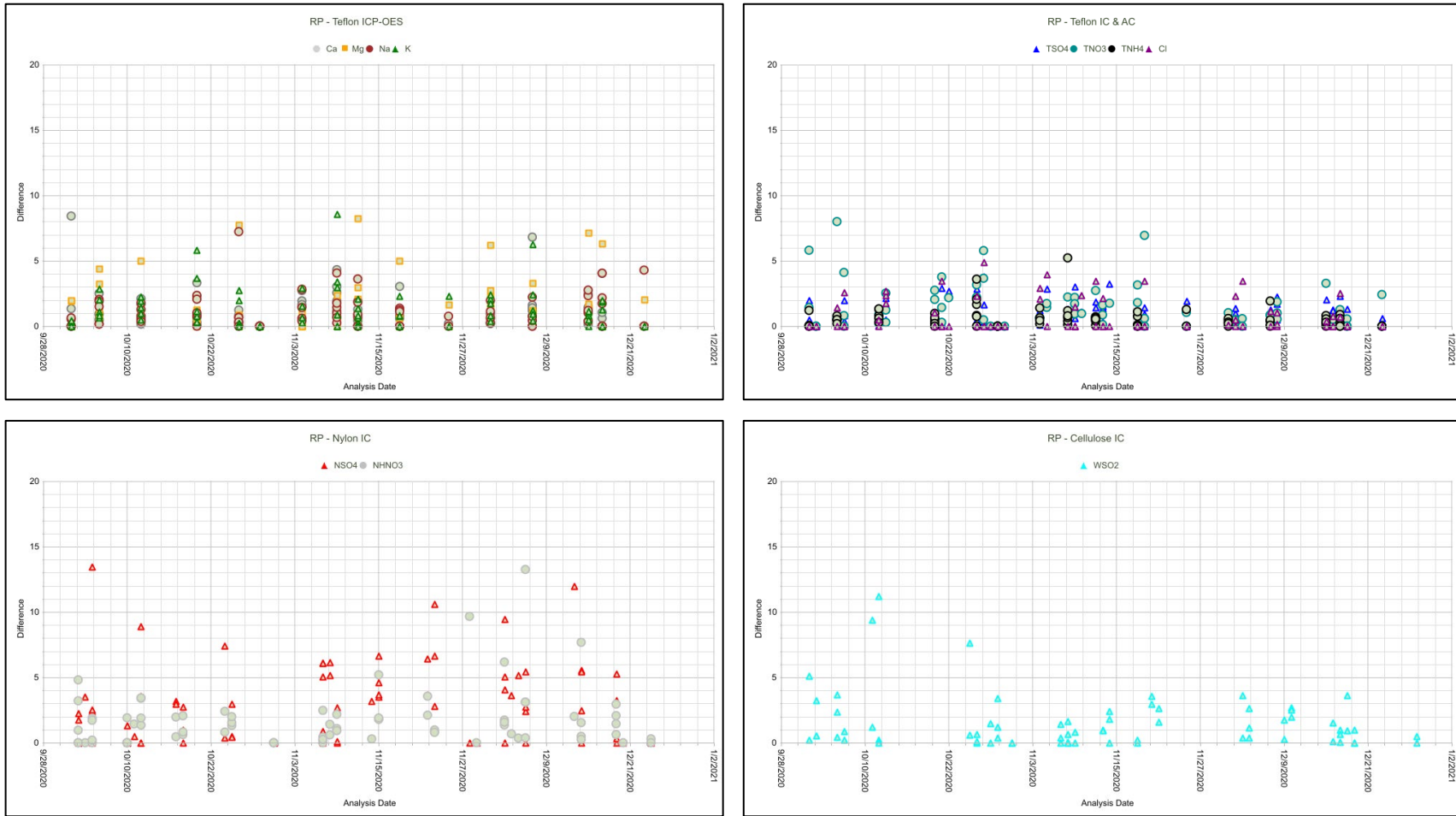
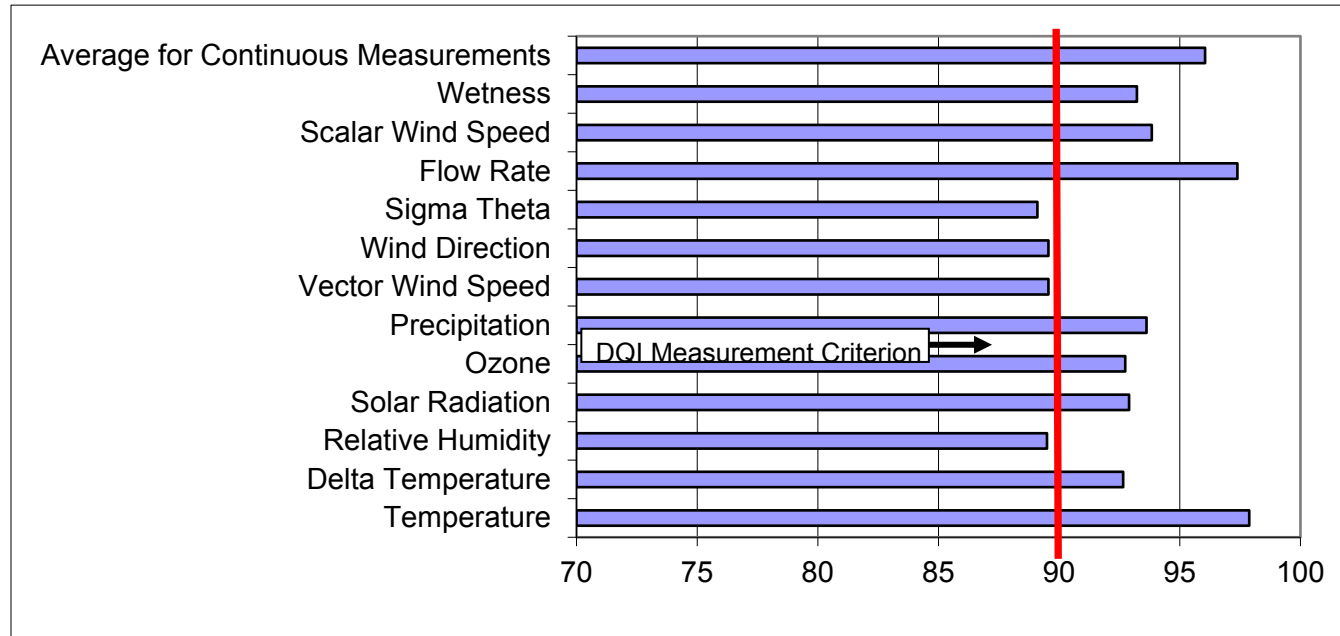


Figure 4 Percent Completeness of Measurements for Second Quarter 2019 through Third Quarter 2020*



Note: *Presents Level 3 data available during the fourth quarter of 2020

Figure 5 Laboratory Control Sample Results for Fourth Quarter 2020 (percent recovery)

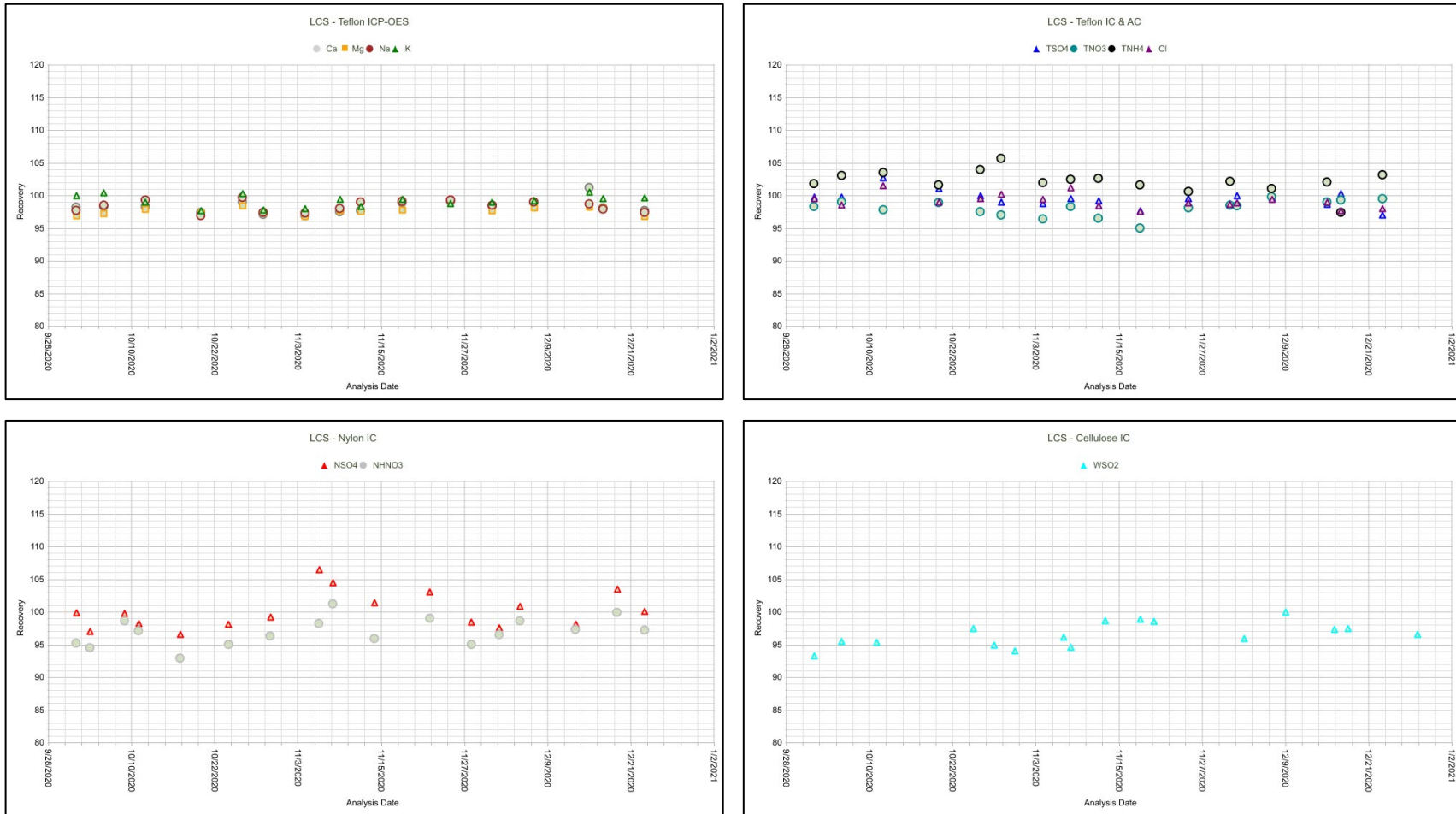


Figure 6 Method Blank Analysis Results for Fourth Quarter 2020 (total micrograms)

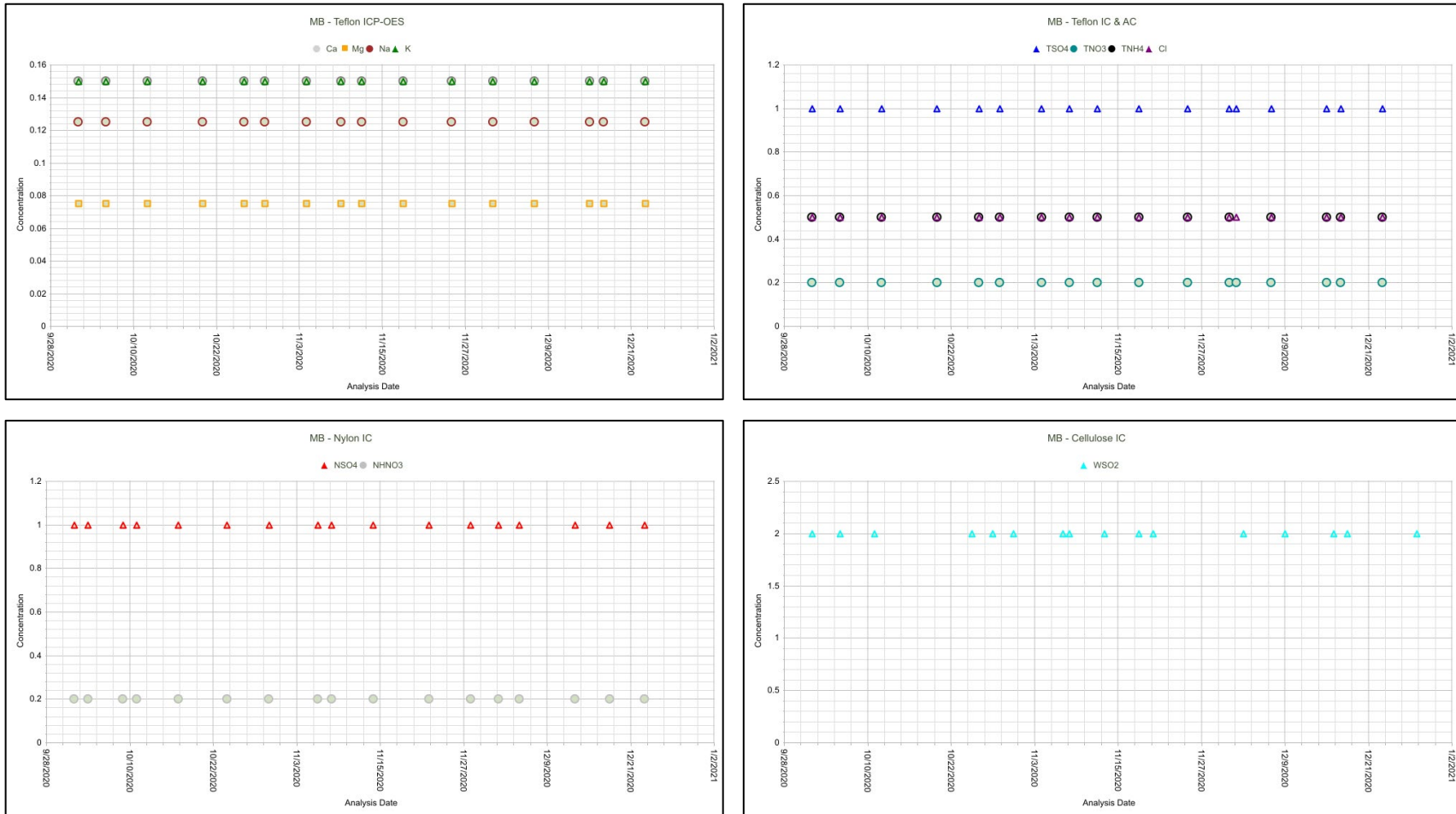


Figure 7 Laboratory Blank Analysis Results for Fourth Quarter 2020 (total micrograms)

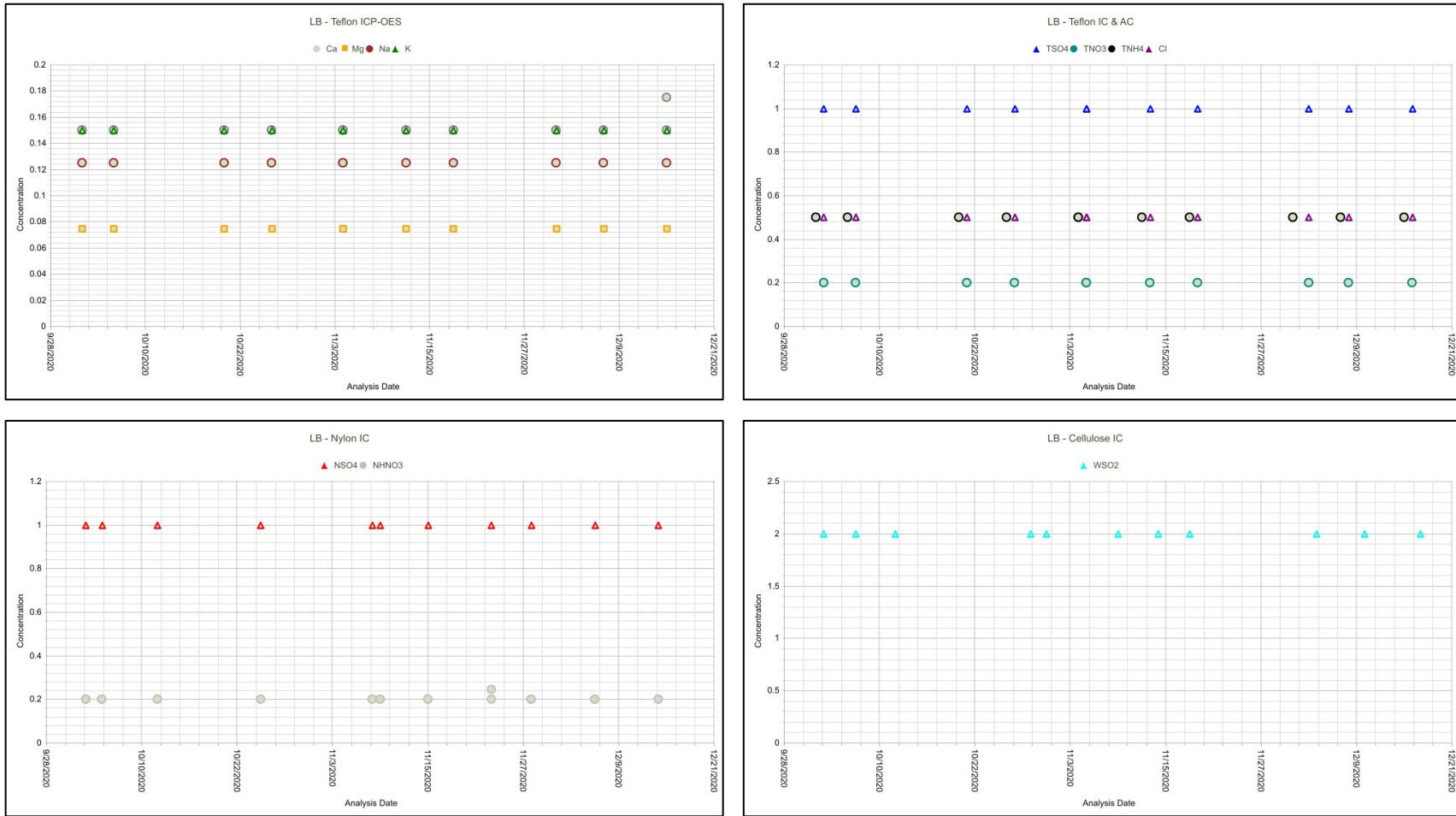


Figure 8 Field Blank Analysis Results for Fourth Quarter 2020 (total micrograms)

