Ion Analysis

2012 IMPROVE Steering Committee Meeting

Incline Village, NV
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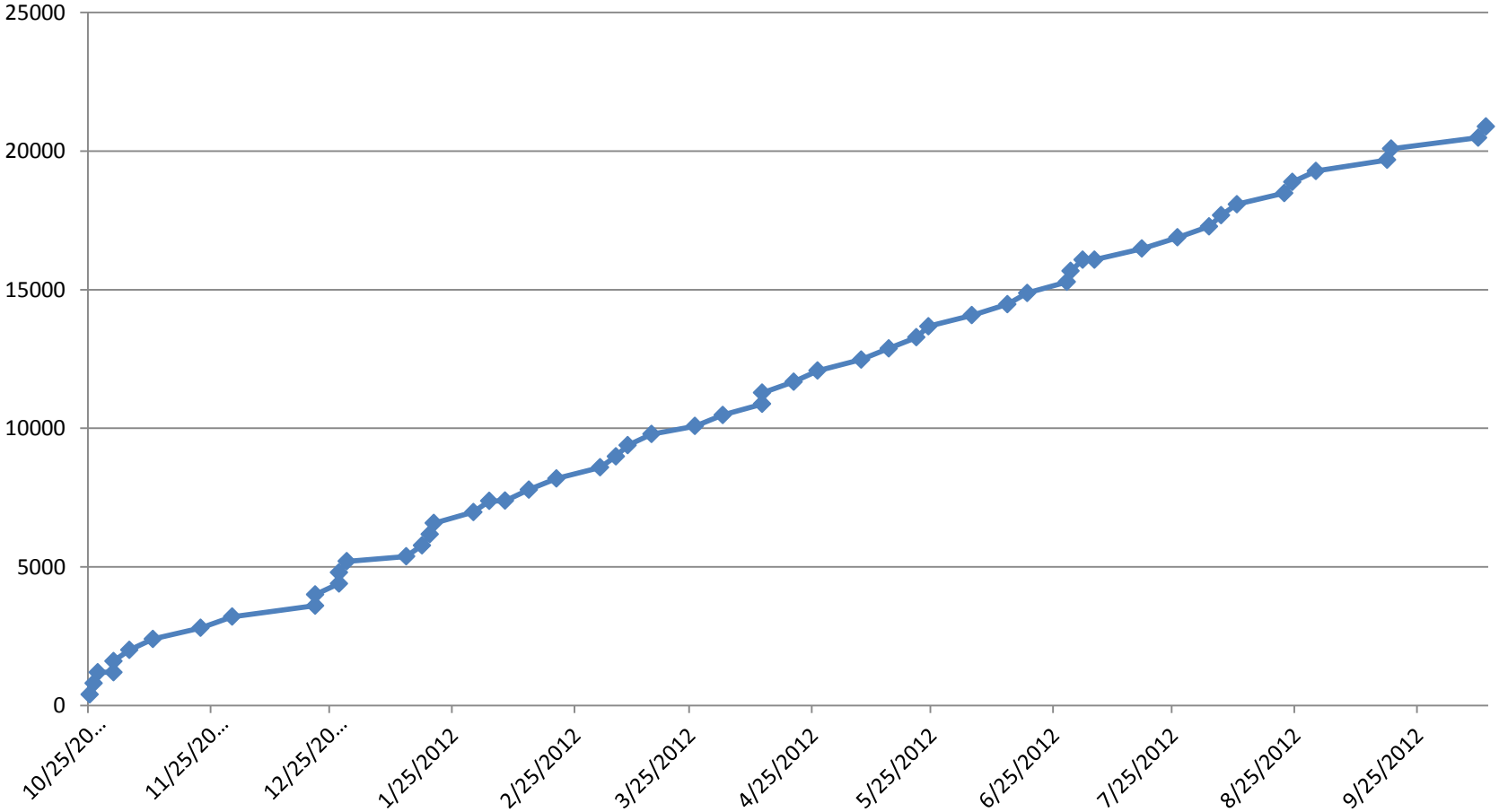
Since the last meeting…

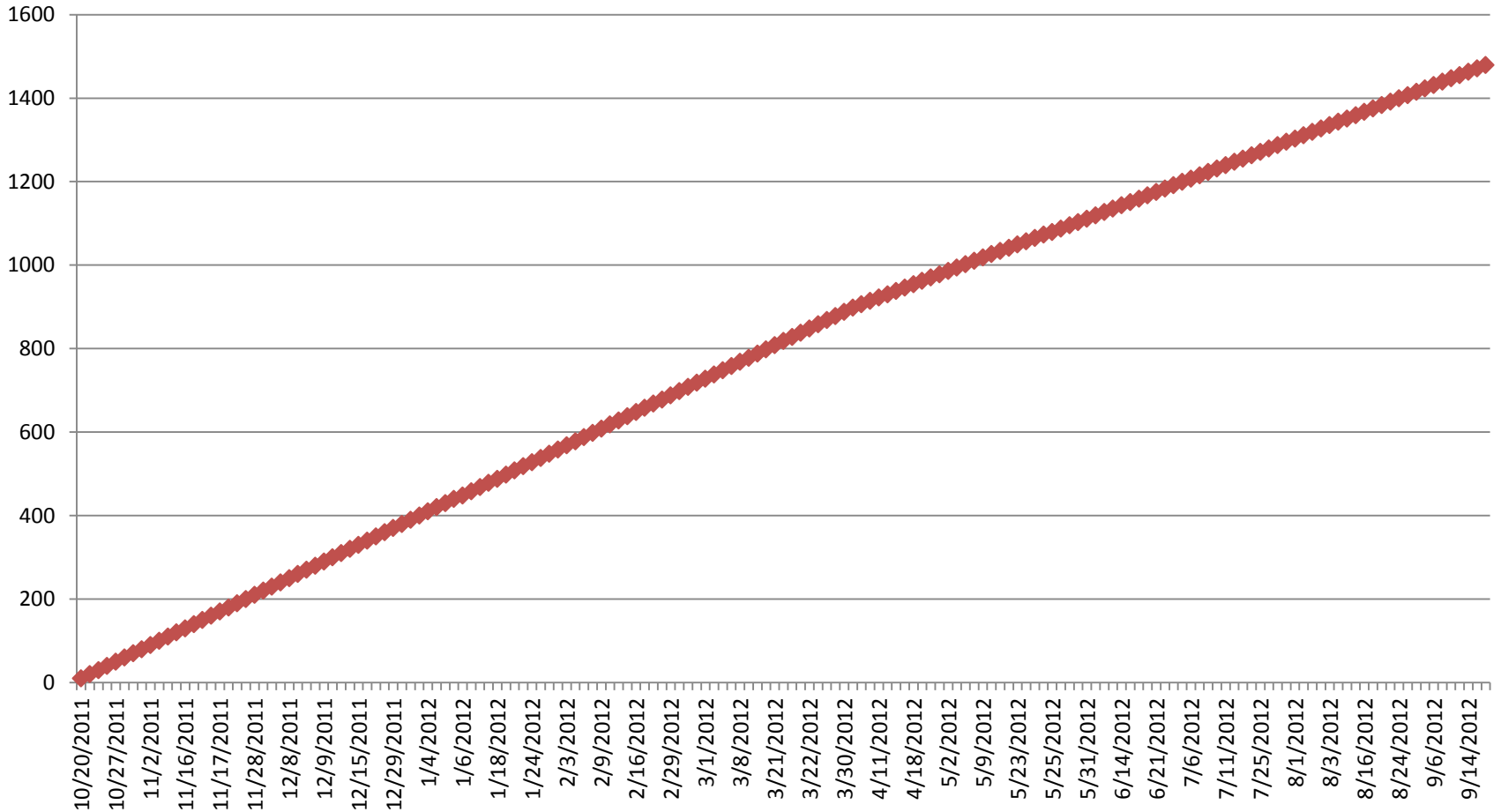
- Dr. Prakash Doraiswamy joined RTI's Environmental Chemistry Department, bringing a new dimension in air quality modeling.

- The RTI Ions Lab
  - received and analyzed ~21,000 nylon filters for anions.
  - received and analyzed ~1500 H_3PO_3-coated cellulose filters for ammonia (as ammonium ion) for the NH_x Pilot Study.
  - retrieved the corresponding nylon filter extracts and analyzed them for ammonium and potassium ions.
  - participated in the technical systems audit (TSA) conducted by NAREL at RTI on July 24-25, 2012.

Nylon Filters Received from UC-Davis (cumulative)



H_3PO_3-Coated Cellulose Filters (in cartridges) Received from the NH_x Sites (cumulative)



Ion Chromatography Lab audit by NAREL – July 24-25, 2012

Table 7. Demonstration of Anion and Cation Analysis During the Audit

Sample_ID	Sample Description	Parameter	Expected Value (ppm)	RTI Result (ppm)
SS12-14282	Anion solution provided by NAREL	Fluoride	0.00	not reported
		Chloride	1.00	1.03
		Nitrite	1.00	1.00
		Nitrate	2.00	2.00
		Sulfate	3.00	3.07
SS12-14283	Cation solution provided by NAREL	Lithium	0.25	not reported
		Sodium	1.00	1.02
		Ammonium	2.00	2.08
		Potassium	1.00	1.00
		Magnesium	1.00	not reported
		Calcium	5.00	not reported

Ion Chromatography Lab audit by NAREL – July 24-25, 2012, cont'd

Table 8. RTI Calibration Standards Analyzed at NAREL After the Audit

Sample_ID	Sample Description	Parameter	Expected Value (ppm)	NAREL Result (ppm)
SS12-14284	Anion standard provided by RTI	Chloride	1.00	1.03
		Nitrite	2.00	2.00
		Nitrate	3.00	3.08
		Sulfate	6.00	6.03
SS12-14285	Cation standard provided by RTI	Sodium	4.00	3.93
		Ammonium	4.00	3.97
		Potassium	4.00	3.88

Analysis of levoglucosan on PTFE (Teflon®) filters

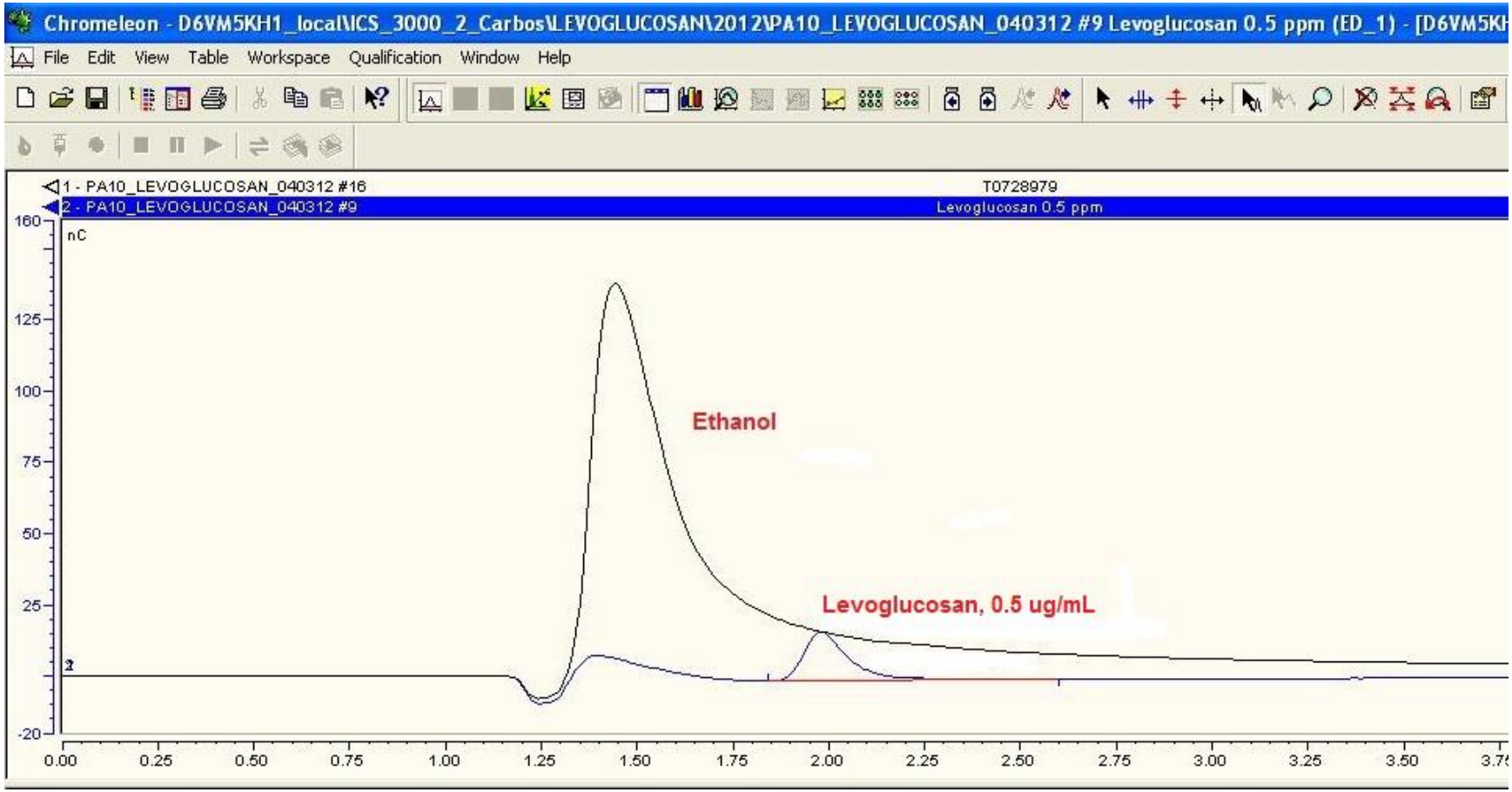
- ECD's Ion Analysis Lab received from EPA four 47-mm PTFE filters for levoglucosan analysis.
- Filters were extracted using the PM2.5 PTFE filter extraction procedure:
  - Place filter in 50-mL centrifuge tube.
  - Using an Eppendorf pipette, slowly wet the filter with 100 µL ethanol.
  - Add 25.0 mL DI H_2O.
  - Place tube in an ultrasonic bath and sonicate for 60 min.
  - Shake overnight at 60 cycles per minute on a mechanical shaker in a coldroom (≤4 C).

Analysis of levoglucosan on PTFE (Teflon®) filters, cont'd

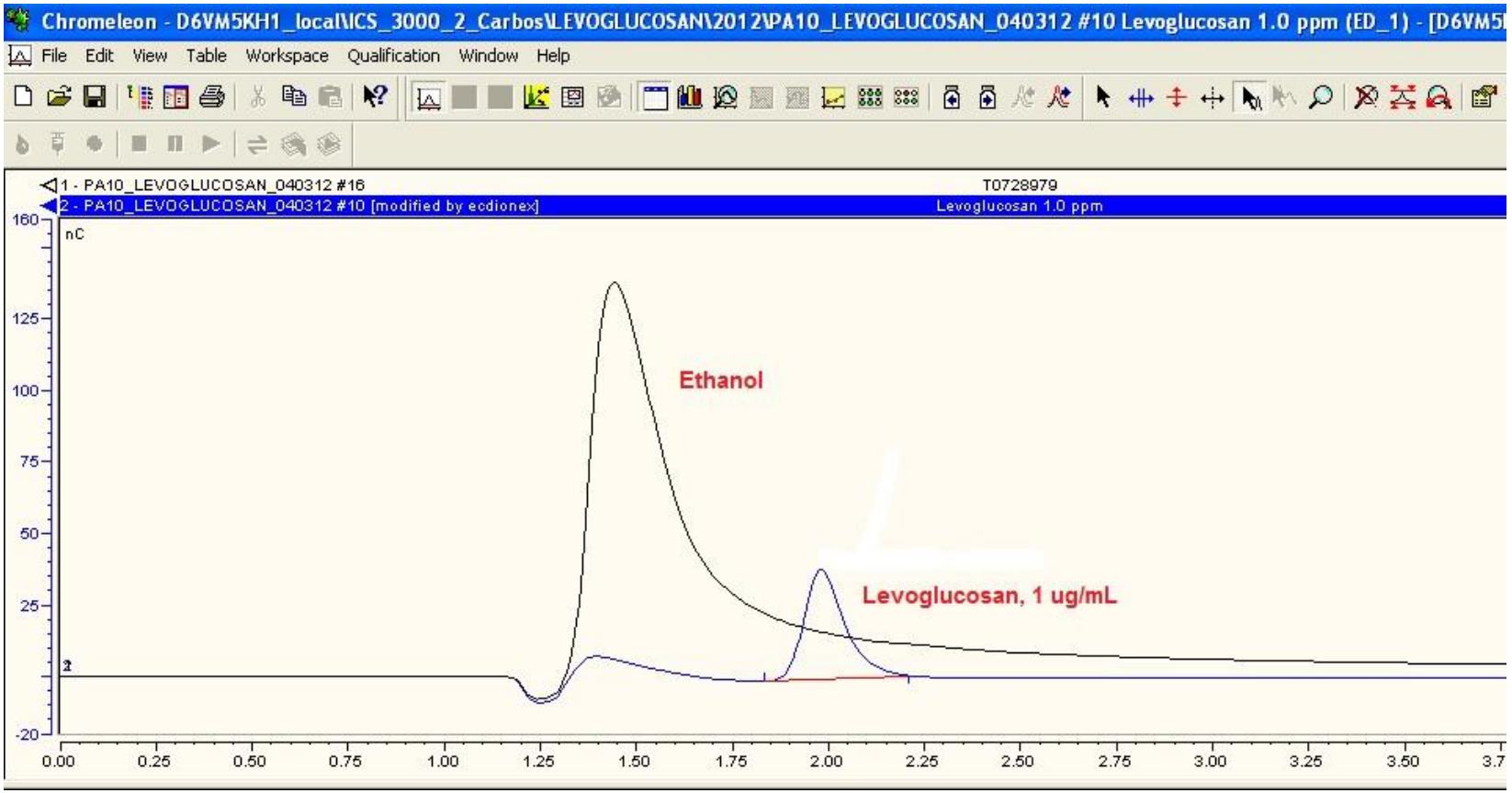
- Extracts were analyzed on a Dionex Model 3000 IC equipped with a PA10 separator column, an eluent generator, a KOH eluent cartridge, and a Dionex electrochemical detector.

- An interference with the levoglucosan peak was identified as arising from the ethanol in the extract.

Ethanol interference in analysis of levoglucosan by ion chromatography (RTI)



Ethanol interference in analysis of levoglucosan by ion chromatography (RTI)



How do we remove the ethanol interference ?

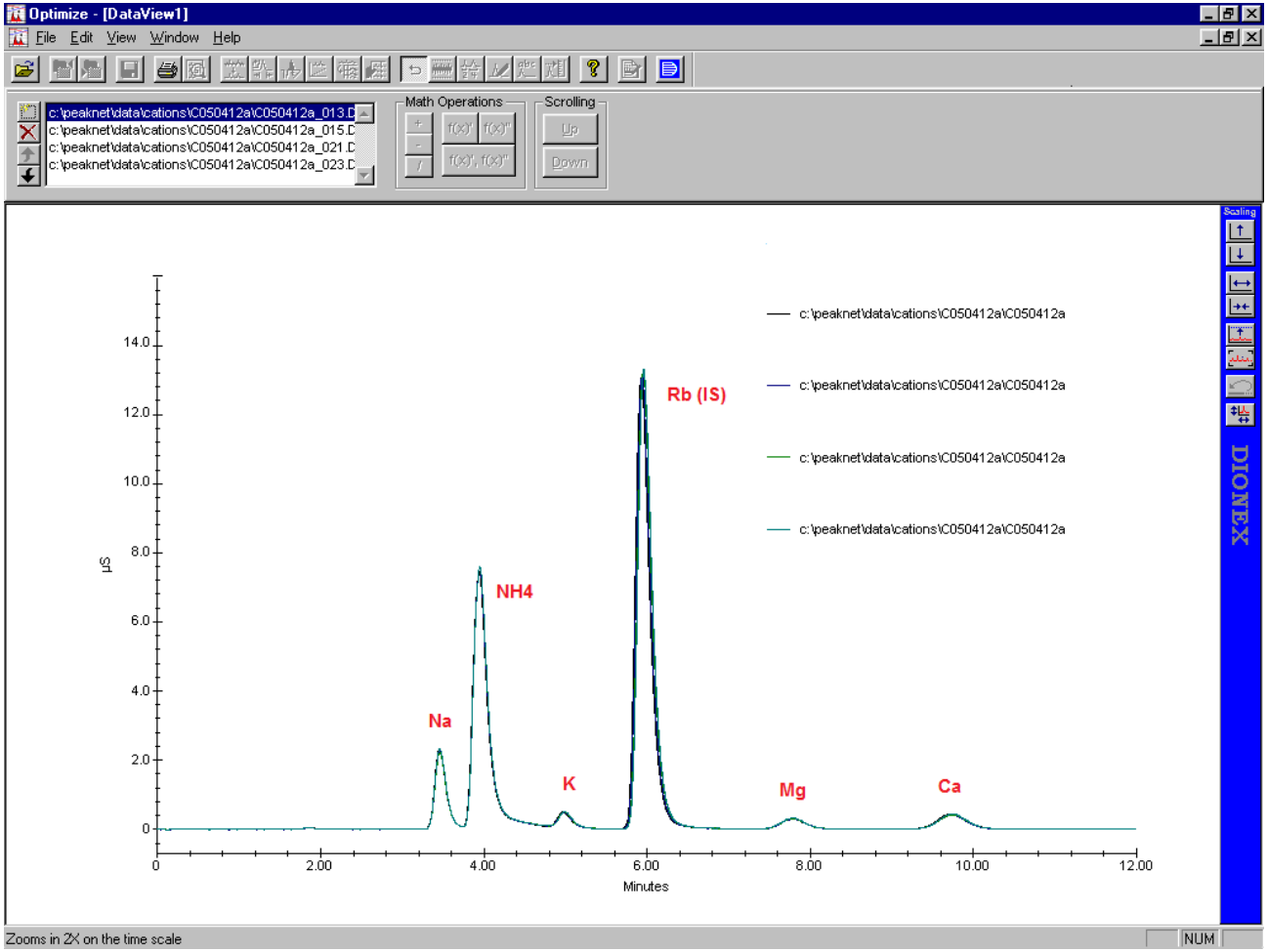
- Freeze-drying can be used to remove the ethanol, but it is time-consuming and increases price.

- Can we omit the pre-wetting of the PTFE filters with ethanol prior to extraction without compromising extraction efficiency? To help answer this question:
  - Ideally, we need replicate levoglucosan-containing PTFE filters to analyze (half with ethanol pre-wetting and half without) – but it is very unlikely that we would be able to obtain these.
  - Fortunately we have friends in high places ☺ who can collect replicate PM2.5-loaded PTFE filters to test the extraction procedures for ions analysis as a start.

Experimental design

- 16 exposed 47-mm PTFE filter replicates were collected at the NAREL facility in Montgomery (Thanks, Jewell!).
- 12 of the replicates and 6 blank PTFE filters were shipped to RTI for testing the extraction procedure with and without the pre-wetting step.
  - 3 replicates and 2 blanks were pre-wet using 100 µL ethanol prior to extraction and ion analysis
  - 3 replicates and 2 blanks were extracted omitting the pre-wetting step prior to extraction and ion analysis
  - 6 replicates and 2 blanks were stored for additional experiments based upon findings
- 4 of the replicates were retained at NAREL for QA (duplication of RTI experiments described above).

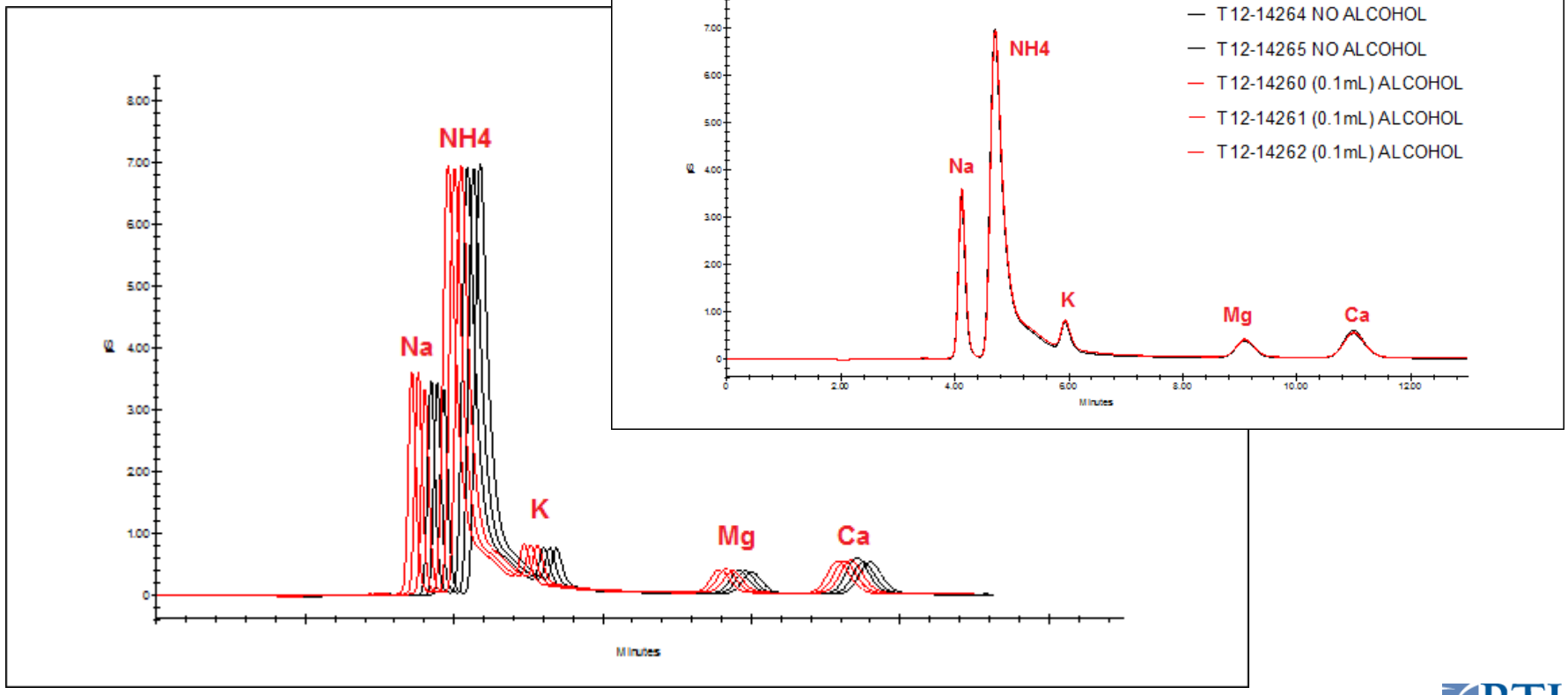
Cation analysis of replicate 47-mm PTFE filters by NAREL (with and w/o ethanol pre-wetting)



Cation analysis of replicate 47-mm PTFE filters by NAREL (with and w/o ethanol pre-wetting)

Sample ID	Sample Description	Extraction Method	Cations (µg/filter)						Gravimetric
			Li	Na	NH4	K	Mg	Ca	$PM_{2.5}$ Mass (µg)
B050312a	method blank w/o filter	0.1 mL EtOH + 25 mL H2O	ND	0.24	ND	ND	ND	-0.19	-----
B050312b	method blank w/o filter	25 mL H2O (no EtOH)	ND	ND	ND	ND	ND	-0.52	-----
T12-14272	blank PTFE filter	0.1 mL EtOH + 25 mL H2O	ND	0.47	ND	ND	ND	0.16	-----
T12-14273	blank PTFE filter	0.1 mL EtOH + 25 mL H2O	ND	0.47	-0.01	0.28	ND	-0.03	-----
T12-14274	blank PTFE filter	25 mL H2O (no EtOH)	ND	0.13	ND	ND	ND	0.08	-----
T12-14275	blank PTFE filter	25 mL H2O (no EtOH)	ND	0.10	ND	ND	ND	-0.55	-----
T12-14268	exposed PTFE filter rep	0.1 mL EtOH + 25 mL H2O	ND	10.90	66.91	4.32	1.65	3.14	869
T12-14269	exposed PTFE filter rep	0.1 mL EtOH + 25 mL H2O	ND	10.48	67.99	4.21	1.60	2.96	876
T12-14270	exposed PTFE filter rep	25 mL H2O (no EtOH)	ND	10.30	68.07	4.38	1.63	3.10	876
T12-14271	exposed PTFE filter rep	25 mL H2O (no EtOH)	ND	10.65	66.58	4.06	1.71	3.39	891

Cation analysis of replicate 47-mm PTFE filters by RTI (with and w/o ethanol pre-wetting)

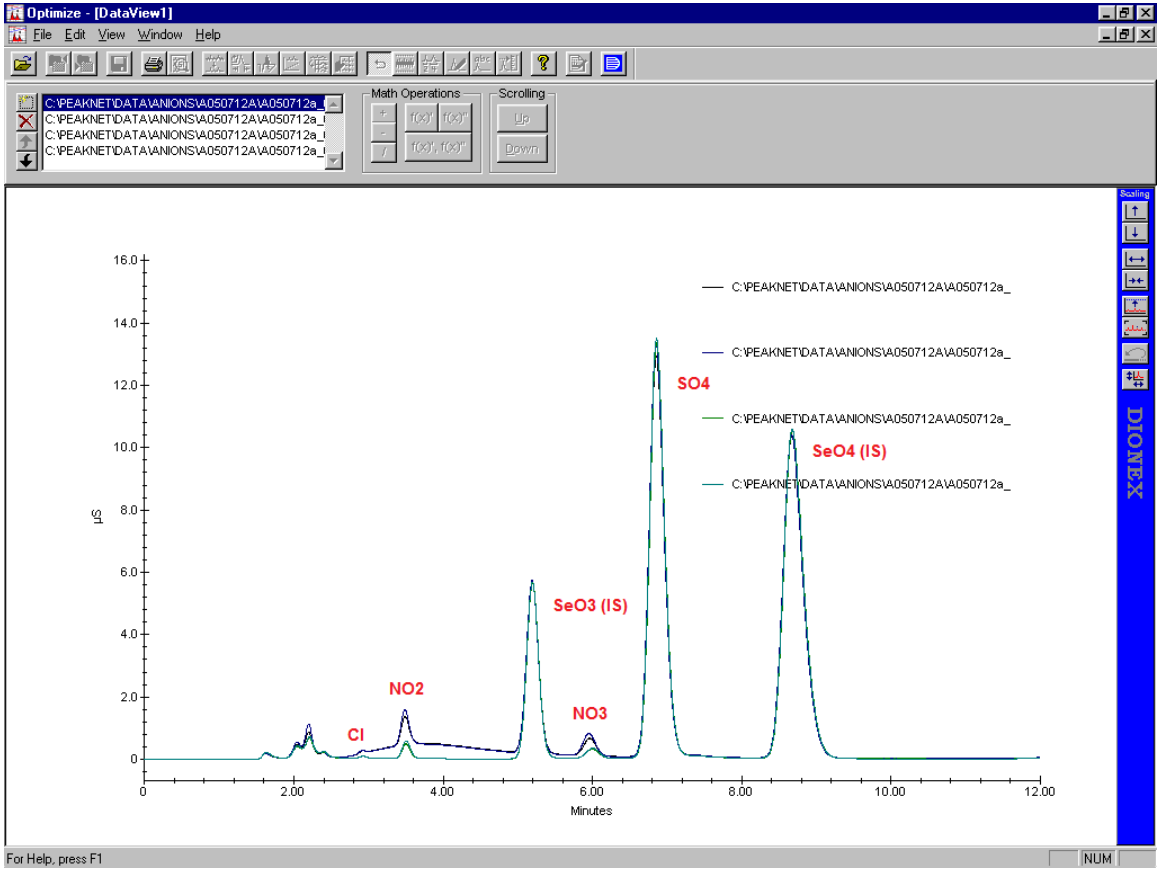


Cation analysis of replicate 47-mm PTFE filters by RTI (with and w/o ethanol pre-wetting)

Sample ID	Sample Description	Extraction Method	Cations (µg/filter) Na	NH4	K	Gravimetric $PM_{2.5}$ Mass (µg)
Tube Blk A	method blank w/o filter	0.1 mL EtOH + 25 mL H2O	ND	ND	ND	-----
Tube Blk B	method blank w/o filter	25 mL H2O (no EtOH)	ND	ND	ND	-----
T22-23431	blank PTFE filter	0.1 mL EtOH + 25 mL H2O	0.37	0.00	0.00	-----
T22-23432	blank PTFE filter	0.1 mL EtOH + 25 mL H2O	0.38	0.00	0.00	-----
T22-23433	blank PTFE filter	25 mL H2O (no EtOH)	1.02	0.00	0.58	-----
T22-23434	blank PTFE filter	25 mL H2O (no EtOH)	0.28	0.00	0.00	-----
T12-14260	exposed PTFE filter rep	0.1 mL EtOH + 25 mL H2O	10.05	79.53	3.43	881
T12-14261	exposed PTFE filter rep	0.1 mL EtOH + 25 mL H2O	10.86	78.16	3.56	880
T12-14262	exposed PTFE filter rep	0.1 mL EtOH + 25 mL H2O	10.85	79.22	3.61	883
T12-14263	exposed PTFE filter rep	25 mL H2O (no EtOH)	9.98	79.44	3.46	868
T12-14264	exposed PTFE filter rep	25 mL H2O (no EtOH)	10.31	77.91	3.46	886
T12-14265	exposed PTFE filter rep	25 mL H2O (no EtOH)	10.38	78.53	3.58	891

Comparison of NAREL and RTI cation analyses

	Sample ID	Extraction Method	Cations (µg/filter) Li	Na	NH4	K	Mg	Ca	$PM_{2.5}$ Mass (µg)
NAREL	T12-14268	0.1 mL EtOH + 25 mL H2O	ND	10.90	66.91	4.32	1.65	3.14	869
	T12-14269	0.1 mL EtOH + 25 mL H2O	ND	10.48	67.99	4.21	1.60	2.96	876
RTI	T12-14260	0.1 mL EtOH + 25 mL H2O	NA	10.05	79.53	3.43	NA	NA	881
	T12-14261	0.1 mL EtOH + 25 mL H2O	NA	10.86	78.16	3.56	NA	NA	880
	T12-14262	0.1 mL EtOH + 25 mL H2O	NA	10.85	79.22	3.61	NA	NA	883
NAREL	T12-14270	25 mL H2O (no EtOH)	ND	10.30	68.07	4.38	1.63	3.10	876
	T12-14271	25 mL H2O (no EtOH)	ND	10.65	66.58	4.06	1.71	3.39	891
RTI	T12-14263	25 mL H2O (no EtOH)	NA	9.98	79.44	3.46	NA	NA	868
	T12-14264	25 mL H2O (no EtOH)	NA	10.31	77.91	3.46	NA	NA	886
	T12-14265	25 mL H2O (no EtOH)	NA	10.38	78.53	3.58	NA	NA	891



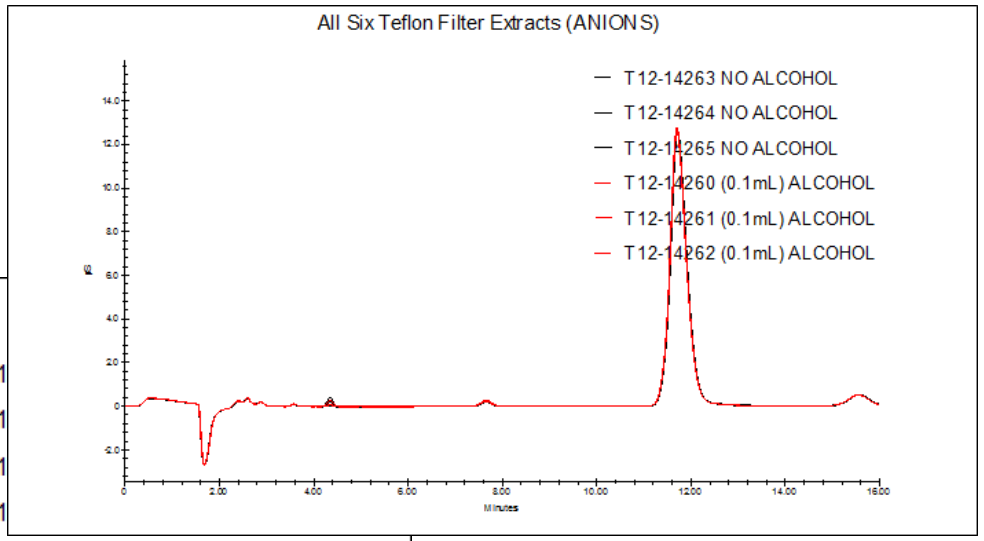
Anion analysis of replicate 47-mm PTFE filters by NAREL (with and w/o ethanol pre-wetting)

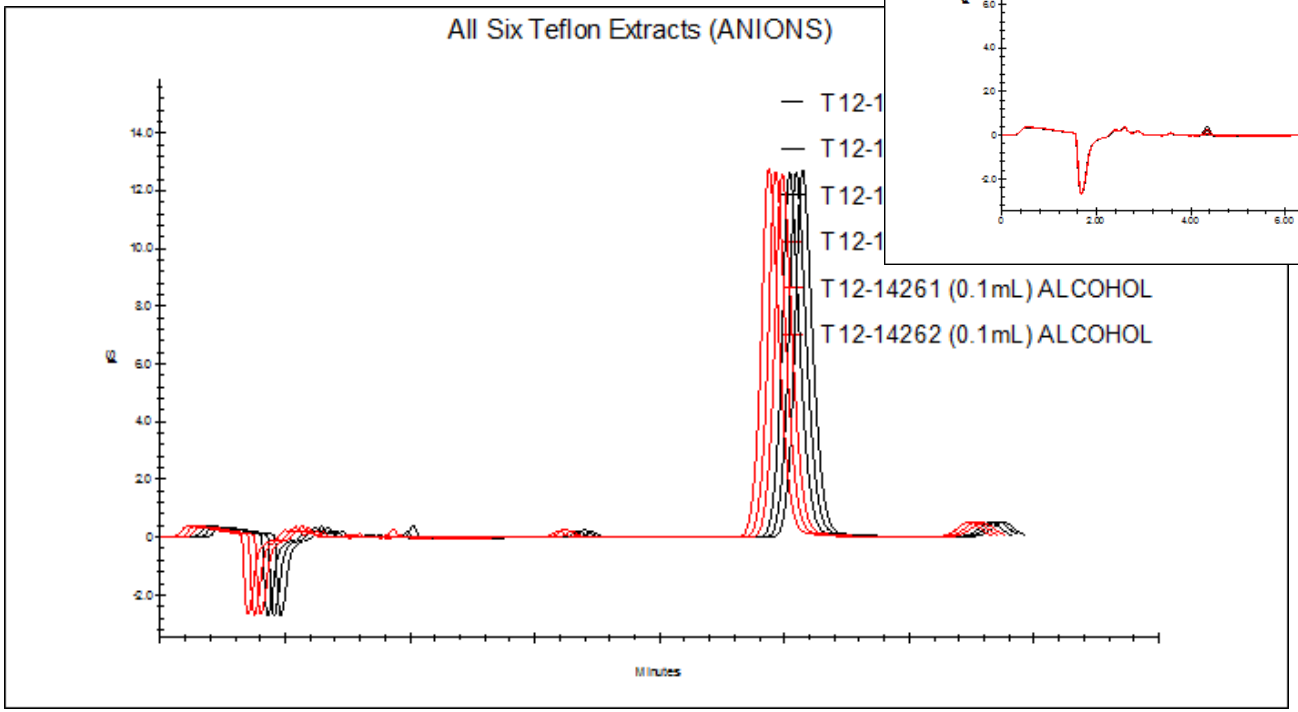
- Ethanol “hump” affects Cl, NO2, and NO3 peaks
- Sulfate peaks are very consistent for filters extracted with and without alcohol.

Anion analysis of replicate 47-mm PTFE filters by NAREL (with and w/o ethanol pre-wetting)

Sample ID	Sample Description	Extraction Method	Anions (µg/filter) F	Cl	NO2	NO3	SO4	Gravimetric $PM_{2.5}$ Mass (µg)
B050312a	method blank w/o filter	0.1 mL EtOH + 25 mL H2O	ND	ND	ND	ND	ND	-----
B050312b	method blank w/o filter	25 mL H2O (no EtOH)	ND	ND	ND	ND	ND	-----
T12-14272	blank PTFE filter	0.1 mL EtOH + 25 mL H2O	0.32	0.22	7.97	2.62	ND	-----
T12-14273	blank PTFE filter	0.1 mL EtOH + 25 mL H2O	0.36	0.23	10.73	4.26	ND	-----
T12-14274	blank PTFE filter	25 mL H2O (no EtOH)	ND	0.06	13.81	2.08	ND	-----
T12-14275	blank PTFE filter	25 mL H2O (no EtOH)	ND	0.04	11.67	1.82	ND	-----
T12-14268	exposed PTFE filter rep	0.1 mL EtOH + 25 mL H2O	2.08	0.22	11.74	11.07	211.10	869
T12-14269	exposed PTFE filter rep	0.1 mL EtOH + 25 mL H2O	2.27	0.32	14.41	14.26	218.58	876
T12-14270	exposed PTFE filter rep	25 mL H2O (no EtOH)	1.81	0.33	5.38	5.77	216.21	876
T12-14271	exposed PTFE filter rep	25 mL H2O (no EtOH)	1.89	0.31	6.52	6.33	222.20	891

Anion analysis of replicate 47-mm PTFE filters by RTI (with and w/o ethanol pre-wetting)





Anion analysis of replicate 47-mm PTFE filters by RTI (with and w/o ethanol pre-wetting)

Sample ID	Sample Description	Extraction Method	Anions (µg/filter)					Gravimetric
			F	Cl	NO2	NO3	SO4	$PM_{2.5}$ Mass (µg)
Tube Blank	Tube Blank	0.1 mL EtOH + 25 mL H2O	NA	0.07	0.00	0.00	0.00	-----
Tube Blank	Tube Blank	25 mL H2O (no EtOH)	NA	0.12	0.00	0.45	0.00	-----
T22-23431	blank PTFE filter	0.1 mL EtOH + 25 mL H2O	NA	0.41	0.58	0.64	0.47	-----
T22-23432	blank PTFE filter	0.1 mL EtOH + 25 mL H2O	NA	0.36	0.00	0.50	0.00	-----
T22-23433	blank PTFE filter	25 mL H2O (no EtOH)	NA	1.46	0.80	0.57	0.27	-----
T22-23434	blank PTFE filter	25 mL H2O (no EtOH)	NA	0.30	2.41	0.81	0.26	-----
T12-14260	exposed PTFE filter rep	0.1 mL EtOH + 25 mL H2O	NA	0.44	1.23	4.04	216.17	868
T12-14261	exposed PTFE filter rep	0.1 mL EtOH + 25 mL H2O	NA	0.29	2.62	4.94	217.28	886
T12-14262	exposed PTFE filter rep	0.1 mL EtOH + 25 mL H2O	NA	0.30	1.04	3.69	219.45	891
T12-14263	exposed PTFE filter rep	25 mL H2O (no EtOH)	NA	0.28	0.83	3.60	219.46	881
T12-14264	exposed PTFE filter rep	25 mL H2O (no EtOH)	NA	0.31	3.56	4.33	218.03	880
T12-14265	exposed PTFE filter rep	25 mL H2O (no EtOH)	NA	0.27	2.15	4.16	218.62	883

Comparison of NAREL and RTI anion analyses

	Sample ID	Sample Description	Extraction Method	Anions (µg/filter) F	Cl	NO2	NO3	SO4	Gravimetric $PM_{2.5}$ Mass (µg)
NAREL	T12-14268	exposed PTFE filter rep	0.1 mL EtOH + 25 mL H2O	2.08	0.22	11.74	11.07	211.10	869
	T12-14269	exposed PTFE filter rep	0.1 mL EtOH + 25 mL H2O	2.27	0.32	14.41	14.26	218.58	876
RTI	T12-14260	exposed PTFE filter rep	0.1 mL EtOH + 25 mL H2O	NA	0.44	1.23	4.04	216.17	868
	T12-14261	exposed PTFE filter rep	0.1 mL EtOH + 25 mL H2O	NA	0.29	2.62	4.94	217.28	886
	T12-14262	exposed PTFE filter rep	0.1 mL EtOH + 25 mL H2O	NA	0.30	1.04	3.69	219.45	891
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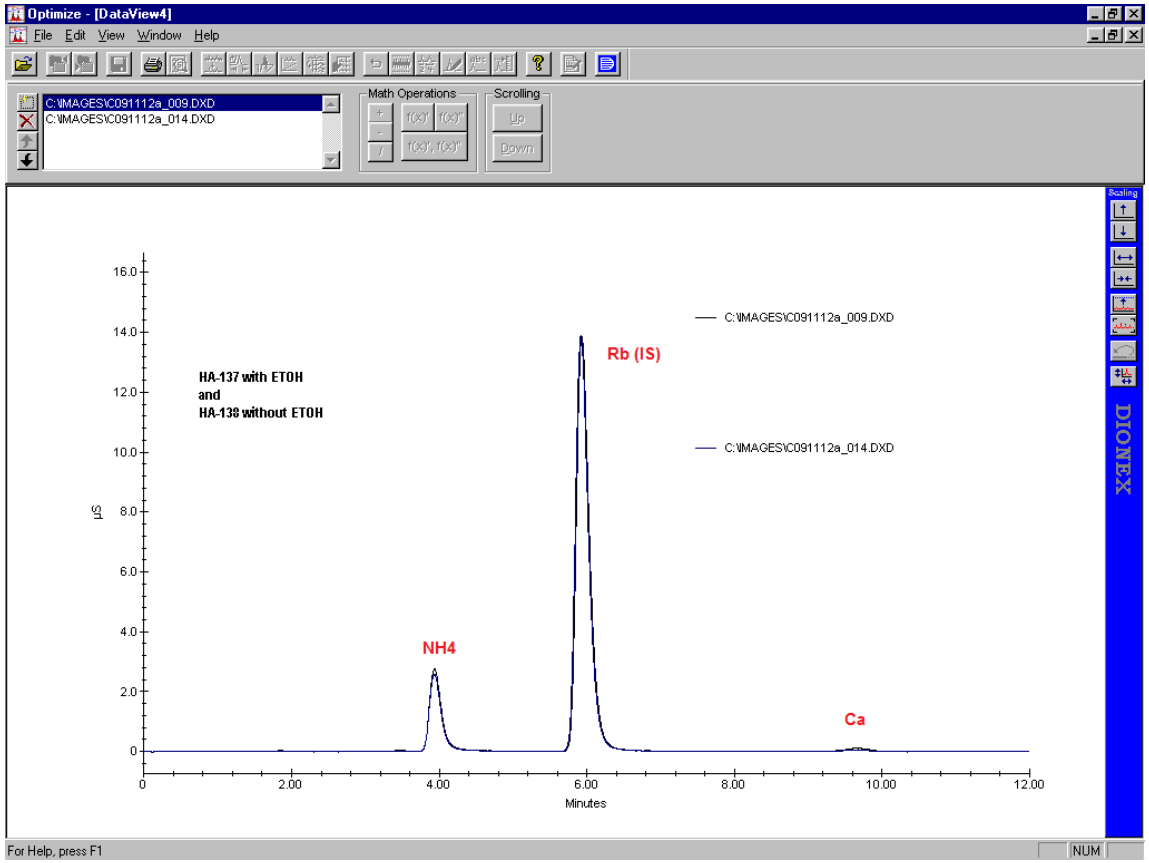
	T12-14271	exposed PTFE filter rep	25 mL H2O (no EtOH)	1.89	0.31	6.52	6.33	222.20	891
RTI	T12-14263	exposed PTFE filter rep	25 mL H2O (no EtOH)	NA	0.28	0.83	3.60	219.46	881
	T12-14264	exposed PTFE filter rep	25 mL H2O (no EtOH)	NA	0.31	3.56	4.33	218.03	880
	T12-14265	exposed PTFE filter rep	25 mL H2O (no EtOH)	NA	0.27	2.15	4.16	218.62	883

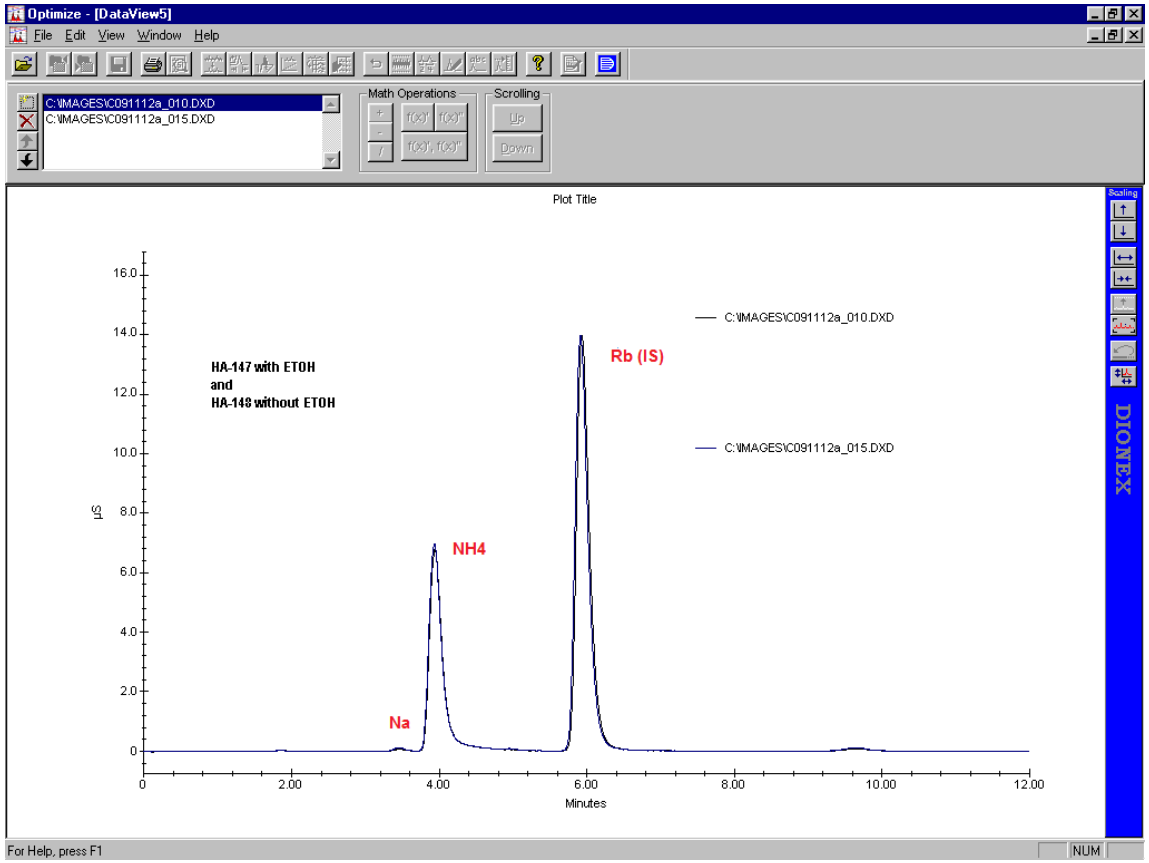
Extraction efficiency experiments

- Ion analyses of replicate PTFE filters extracts with and without filter pre-wetting suggest that pre-wetting might not be necessary, but…
- Is the extraction complete?
  - UC-Davis loaded twelve 25-mm PTFE filters with known quantities of $(NH_4)_2SO_4$ in their aerosol generation chamber – six at a loading of ~ 40 µg and six at a loading of ~ 180 µg (Thanks, Ann and Hardik!)
  - RTI sent two filters at each level to NAREL for extraction, one with and one without ethanol pre-wetting, followed by ion analysis.
  - Remaining eight filters were extracted (four with and four without ethanol pre-wetting) and analyzed by RTI.
  - RTI and NAREL extracted the smaller filters using 15 mL DI H_2O (and 25 µL ethanol for the filters that were pre-wet).

Cation analysis of UCD-loaded 25-mm PTFE filters by NAREL (lower level)



Cation analysis of UCD-loaded 25-mm PTFE filters by NAREL (higher level)



Cation analysis of UCD-loaded 25-mm PTFE filters by NAREL (with and w/o ethanol pre-wetting)

Sample Name	Mass($NH_4)_2SO_4$ µg/filter	Mass NH_4 µg/filter	Cations (µg/filter) Na	NH_4	K	NH_4 % rec
Prep. Blank with 25 µL EtOH (no filter)			-----	-0.10	-----	
Prep. Blank with 25 µL EtOH (with filter)			0.17	0.13	-----	
Prep. Blank w/o EtOH (no filter)			-----	-----	-----	
Prep. Blank w/o EtOH (with filter)			0.08	-----	-----	
HA-137 with 25 µL EtOH	38.9	10.6	0.19	9.43	-----	88.8%
HA-138 w/o EtOH	33.8	9.2	-----	8.77	-----	95.0%
HA-147 with 25 µL EtOH	137.5	37.5	0.18	33.38	-----	88.9%
HA-148 w/o EtOH	140.2	38.3	0.33	35.80	0.36	93.5%
HA-137 Petri Rinse			0.34	-0.06	0.35	
HA-138 Petri Rinse			0.14	-----	0.17	
HA-147 Petri Rinse			0.21	-0.09	0.24	
HA-148 Petri Rinse			0.20	-0.04	0.20	

Cation analysis of UCD-loaded 25-mm PTFE filters by RTI (with and w/o ethanol pre-wetting)

Sample Name	Mass($NH_4)_2SO_4$ µg/filter	Mass NH_4 µg/filter	Cations (µg/filter) Na	NH_4	K	NH_4 % rec
TUBE BLANK with 25µL EtOH			0.00	0.00	0.00	
TUBE BLANK w/o EtOH			0.00	0.00	0.00	
HA-139 with 25µL EtOH	35.1	9.6	0.16	11.02	0.00	115.0%
HA-140 with 25µL EtOH	39.0	10.6	0.56	10.23	0.00	96.1%
HA-141 w/o EtOH	31.2	8.5	0.00	8.30	0.00	97.5%
HA-142 w/o EtOH	34.1	9.3	0.00	8.69	0.00	93.3%
HA-143 with 25µL EtOH	134.1	36.6	0.18	37.26	0.00	101.8%
HA-144 with 25µL EtOH	139.8	38.2	0.16	37.38	0.00	97.9%
HA-145 w/o EtOH	134.5	36.7	0.00	35.74	0.00	97.3%
HA-146 w/o EtOH	137.7	37.6	0.15	35.88	0.00	95.5%

Anion analysis of UCD-loaded 25-mm PTFE filters by NAREL (with and w/o ethanol pre-wetting)

Sample Name	Mass($NH_4)_2SO_4$ µg/filter	Mass SO_4 µg/filter	Anions (µg/filter) Cl	NO_2	NO_3	SO_4	SO_4 % rec
Prep. Blank with 25 µL EtOH (no filter)			-----	-----	-----	-----	
Prep. Blank with 25 µL EtOH (with filter)			0.08	10.98	6.63	-----	
Prep. Blank w/o EtOH (no filter)			-----	-----	-----	-----	
Prep. Blank w/o EtOH (with filter)			-----	0.10	-----	-----	
HA-137 with 25 µL EtOH	38.9	28.3	-----	11.19	6.66	24.99	88.4%
HA-138 w/o EtOH	33.8	24.6	-----	1.93	1.34	22.87	93.1%
HA-147 with 25 µL EtOH (1:5)	137.5	100.0	0.18	-----	0.06	95.85	95.9%
HA-148 w/o EtOH (1:5)	140.2	101.9	0.20	1.59	0.87	96.48	94.7%
HA-137 Petri Rinse			0.41	-----	0.14	-----	
HA-138 Petri Rinse			0.22	-----	0.21	0.03	
HA-147 Petri Rinse			0.22	-----	0.09	-----	
HA-148 Petri Rinse			0.23	-----	0.22	-----	

Anion analysis of UCD-loaded 25-mm PTFE filters by RTI (with and w/o ethanol pre-wetting)

Sample Name:	Mass($NH_4)_2SO_4$, µg/filter	Mass SO_4, µg/filter	Anions (µg/filter) Cl	NO_2	NO_3	SO_4	%rec
TUBE BLANK with 25µL EtOH			0.09	0.30	0.28	0.00	
TUBE BLANK w/o EtOH			0.02	0.37	0.25	0.17	
HA-139 with 25µL EtOH	35.1	25.5	0.10	13.95	13.09	22.88	89.6%
HA-140 with 25µL EtOH	39.0	28.4	0.29	13.55	8.96	25.79	91.0%
HA-141 w/o EtOH	31.2	22.7	0.03	34.40	64.51	21.70	95.7%
HA-142 w/o EtOH	34.1	24.8	0.07	8.58	3.27	22.95	92.6%
HA-143 with 25µL EtOH	134.1	97.5	0.05	12.70	10.13	93.49	95.9%
HA-144 with 25µL EtOH	139.8	101.6	0.07	3.87	2.31	96.56	95.0%
HA-145 w/o EtOH	134.5	97.8	0.08	31.51	44.44	92.64	94.7%
HA-146 w/o EtOH	137.7	100.1	0.08	6.98	3.75	92.86	92.8%

Cation analysis of UCD blank 25-mm PTFE filters by NAREL (with and w/o ethanol pre-wetting)

Sample Name	Cations (µg/filter) Na	NH_4	K
Prep. Blank with 25 µL EtOH (no filter)	0.086	-----	-----
Prep. Blank w/o EtOH (no filter)	-----	-----	-----
BLKAA29025 with 25 µL EtOH	0.169	-0.099	-----
BLKAA29027 with 25 µL EtOH	0.167	-0.064	-----
BLKAA29036 w/o 25 µL EtOH	0.126	-----	-----
BLKAA29010 w/o 25 µL EtOH	0.072	-----	-----

Cation analysis of UCD blank 25-mm PTFE filters by RTI (with and w/o ethanol pre-wetting)

Sample Name:	Cations (µg/filter) Na	NH_4	K
TUBE BLANK 25µL EtOH	0.000	0.000	0.000
TUBE BLANK w/o EtOH	0.000	0.000	0.000
BLANK 5 25µL EtOH	0.000	1.463	0.000
BLANK 6 25µL EtOH	0.137	-0.001	0.000
BLANK 7 25µL EtOH	0.000	0.265	0.000
BLANK 8 w/o EtOH	0.121	0.000	0.000
BLANK 9 w/o EtOH	0.122	0.000	0.000
BLANK 10 w/o EtOH	0.000	0.000	0.000

Anion analysis of UCD blank 25-mm PTFE filters by NAREL (with and w/o ethanol pre-wetting)

	Anions (µg/filter)			
Sample Name	**Cl**	**NO_2**	**NO_3**	**SO_4**
Prep. Blank with 25 µL EtOH (no filter)	-----	-----	-----	-----
Prep. Blank w/o EtOH (no filter)	-----	-----	-----	-----
BLKAA29025 with 25 µL EtOH	-----	5.56	2.32	-----
BLKAA29027 with 25 µL EtOH	0.05	6.79	2.91	-----
BLKAA29036 w/o EtOH	0.04	18.95	7.25	-----
BLKAA29010 w/o EtOH	0.01	10.92	2.33	-----

Anion analysis of UCD blank 25-mm PTFE filters by RTI (with and w/o ethanol pre-wetting)

Sample Name:	Anions (µg/filter) Cl	NO_2	NO_3	SO_4
TUBE BLANK 25µL EtOH	0.02	0.55	0.30	0.00
TUBE BLANK w/o EtOH	0.00	0.00	0.00	0.00
BLANK 5 25µL EtOH	1.80	15.43	19.17	0.23
BLANK 6 25µL EtOH	0.15	7.08	3.73	0.00
BLANK 7 25µL EtOH	0.08	18.63	14.70	0.07
BLANK 8 w/o EtOH	0.06	36.77	19.14	0.00
BLANK 9 w/o EtOH	0.10	17.74	100.42	0.10
BLANK 10 w/o EtOH	0.09	2.98	175.41	0.15

What is the source of the NO_2^- and NO_3^- ?

- What we know:
  - The presence of NO_2^- and NO_3^- on the blank filters is random and the amounts of each are variable.
  - Method/tube blanks and the presence of NO_2^- and NO_3^- in extracts w/o ethanol indicate that the source of the NO_2^- and NO_3^- is not the ethanol itself.
  - No counter-ion is observed in any of the cation chromatograms, but there has to be one.
    - Is the counter-ion H^+?
    - Is HNO_2 or HNO_3 involved in the manufacture/processing of PTFE filters?
    - How is the PTFE membrane attached to the ring?
    - How is the barcode/ID# applied? Is acid etching involved?
- Other ideas ???

Conclusions

- Our preliminary data indicate that pre-wetting PTFE filters with ethanol might not necessary.

- The observation of NO_2^- and NO_3^- on blank filters, and on filters loaded only with $(NH_4)_2SO_4$, appears to be real (i.e., not laboratory contamination). However, we have not identified the source of these ions.

More Information

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