Lithium-ion Battery Thermal Runaway Particle Emissions

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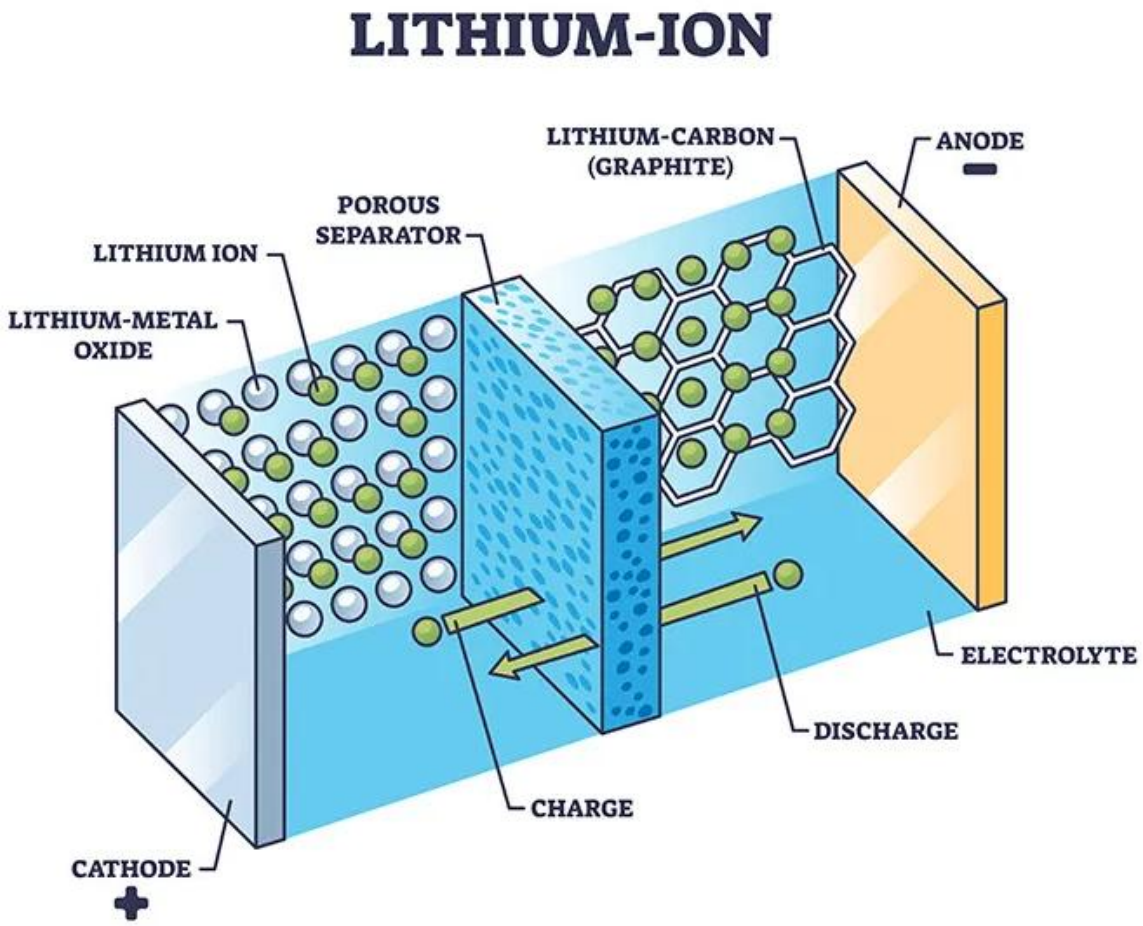
Background



Failure rate is less than 1 in a million, however current production is equivalent to tens of billions of small consumer batteries or tens of millions of EV battery packs produced each year

In the UK, lithium battery fires increased by 93% from 2022-2024.

As of mid-2026, it's reported that the UK has 1 fire every 5 hours.

EPA report 2026 UK fires
Lithium-ion battery statistics
International fire and safety journal

Clean Energy

Moss Landing Battery Fire Leads to Health Fears, Evidence of Contamination and Concerns About Overreaction

Residents describe experiences of sore throats and other symptoms. The energy storage industry insists that this incident is an extreme outlier.

By Dan Gearino, Kiley Price
February 1, 2025

In cleanup from California fires, lithium-ion batteries are a dangerous challenge

The batteries, used in electric vehicles, can explode or ignite if damaged or overheated.

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SMOKE FROM FIRE AT CALIFORNIA LITHIUM BATTERY PLANT RAISES CONCERNS ABOUT AIR QUALITY

Published On January 17, 2025 - 3:10 PM
Written By OLGA R. RODRIGUEZ And ISABELLA O'MALLEY Associated Press

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NEWS

LITHIUM-ION BATTERIES BURN FOR DAYS AFTER SAN PEDRO BIG RIG CRASH

PRINT

Friday, September 27, 2024
LAFD Spokesperson: Nicholas Prange

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U.S. NEWS

Cargo ship carrying burning lithium-ion batteries reaches Alaska, but kept offshore for safety

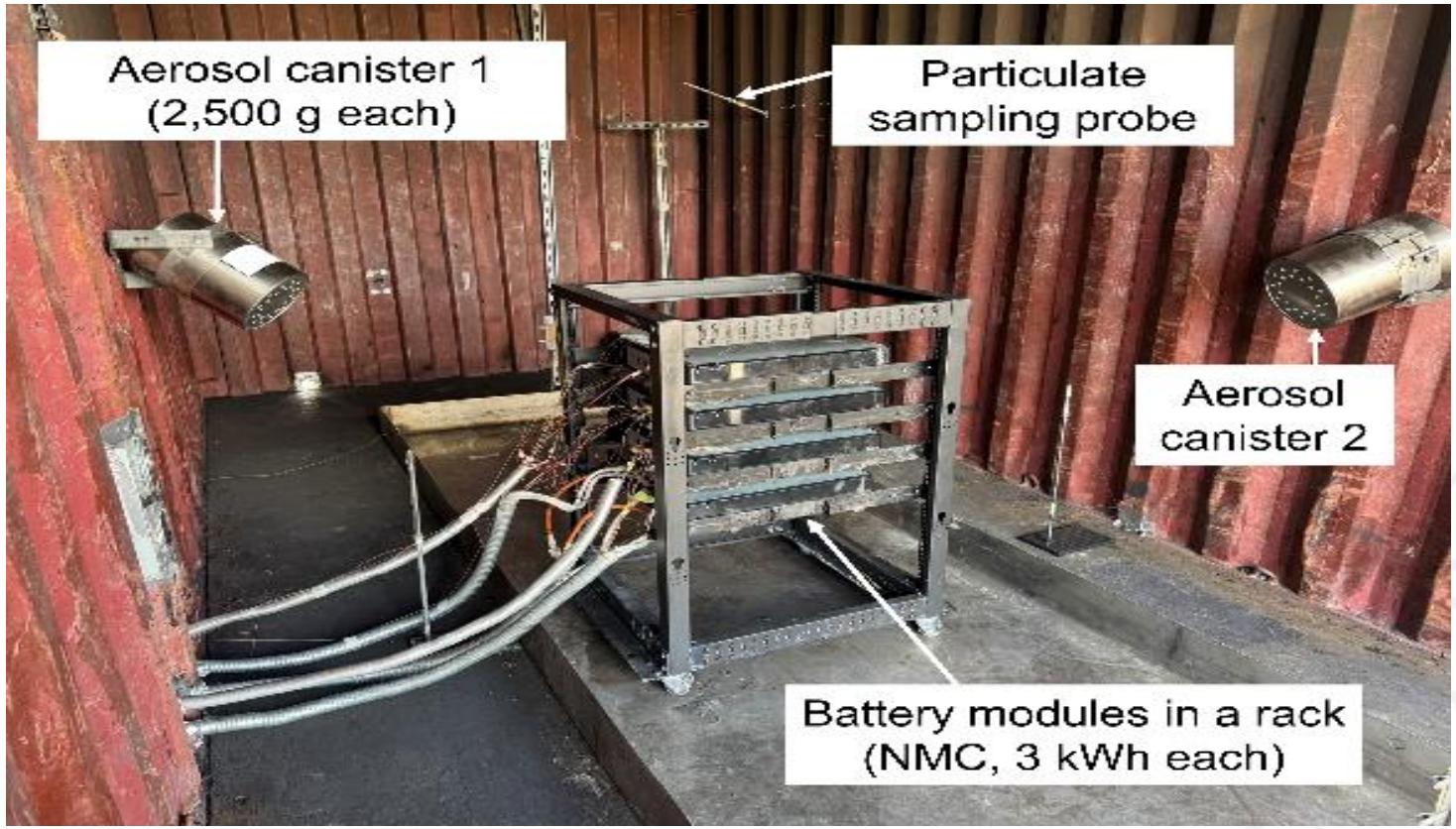
Volkswagen recalls more than 44,000 US EVs over battery fire risks

The recall covers two separate recalls for 2023–2025 model-year vehicles, which involve dealers updating battery software and replacing packs if necessary.

Multiple agencies fight battery storage fire at Glendale-Peoria border

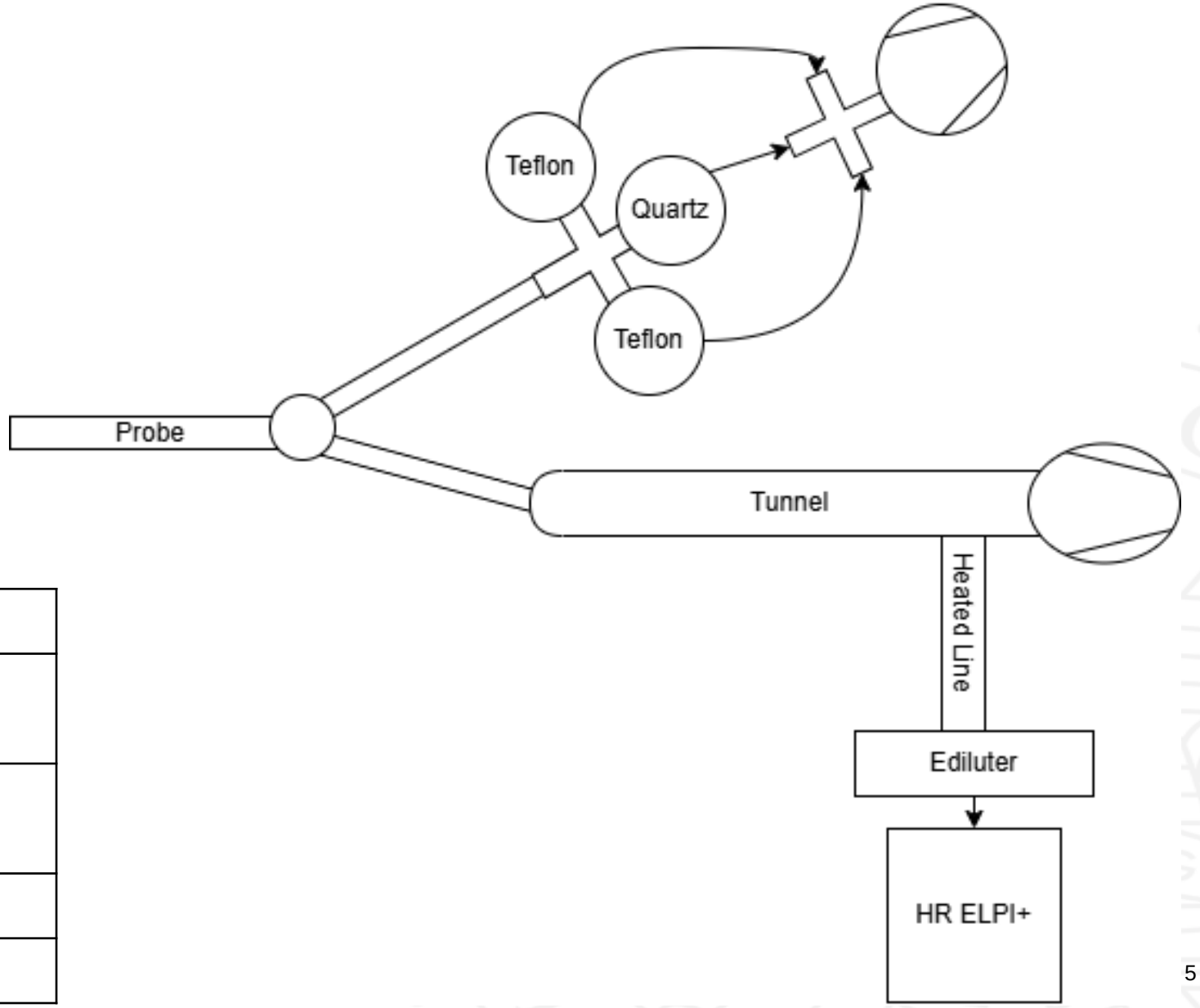
The Salt River Project, known as SRP, is aware of the fire at its 25-megawatt battery system at its Bolster substation. Stephanie Duprey reports.

Measurement Setup



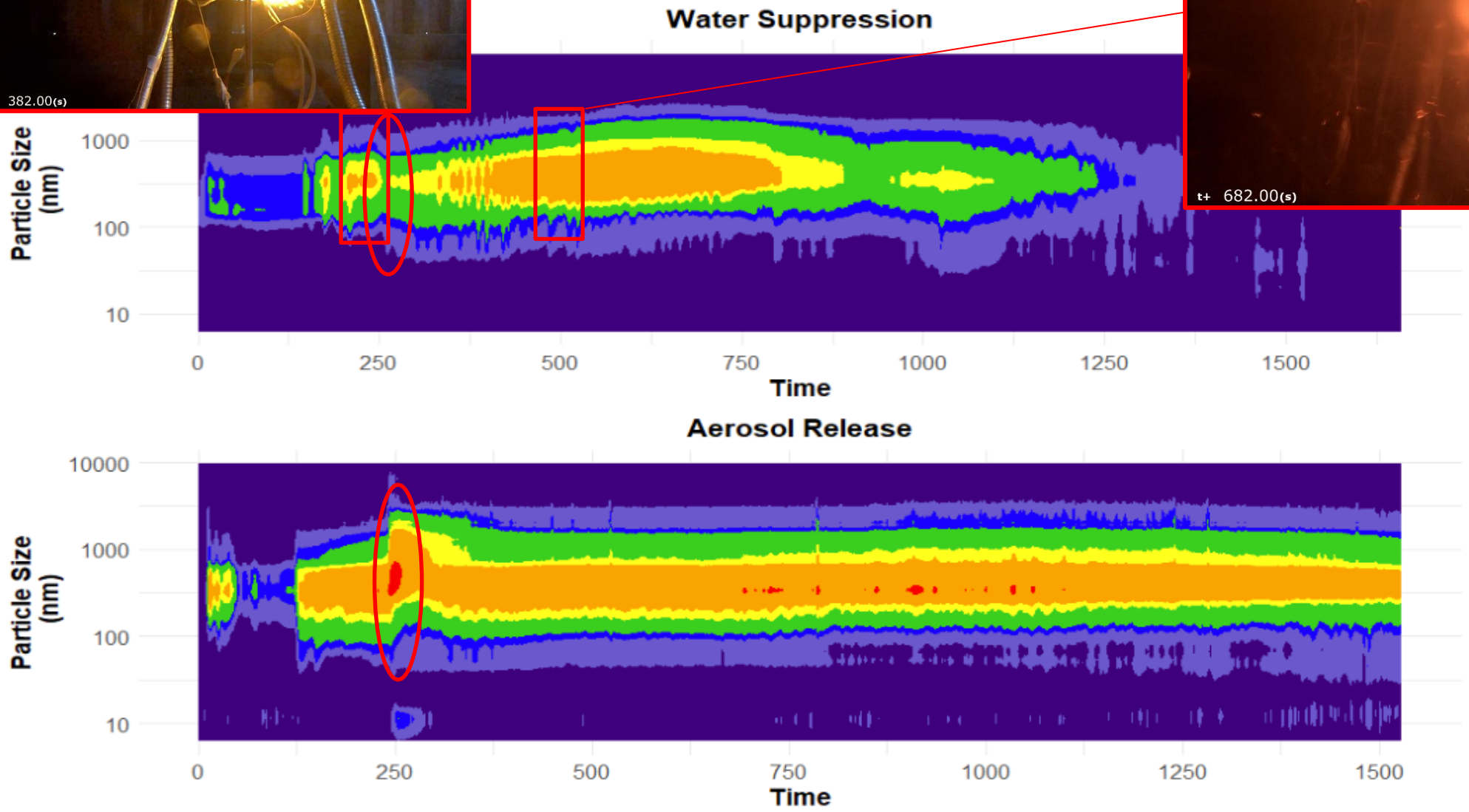
Sampling System

- Filter flow: 12 lpm
- Tunnel flow: 27-57 lpm
- Dilution: 25-195 DR
- Heated line: 150℃



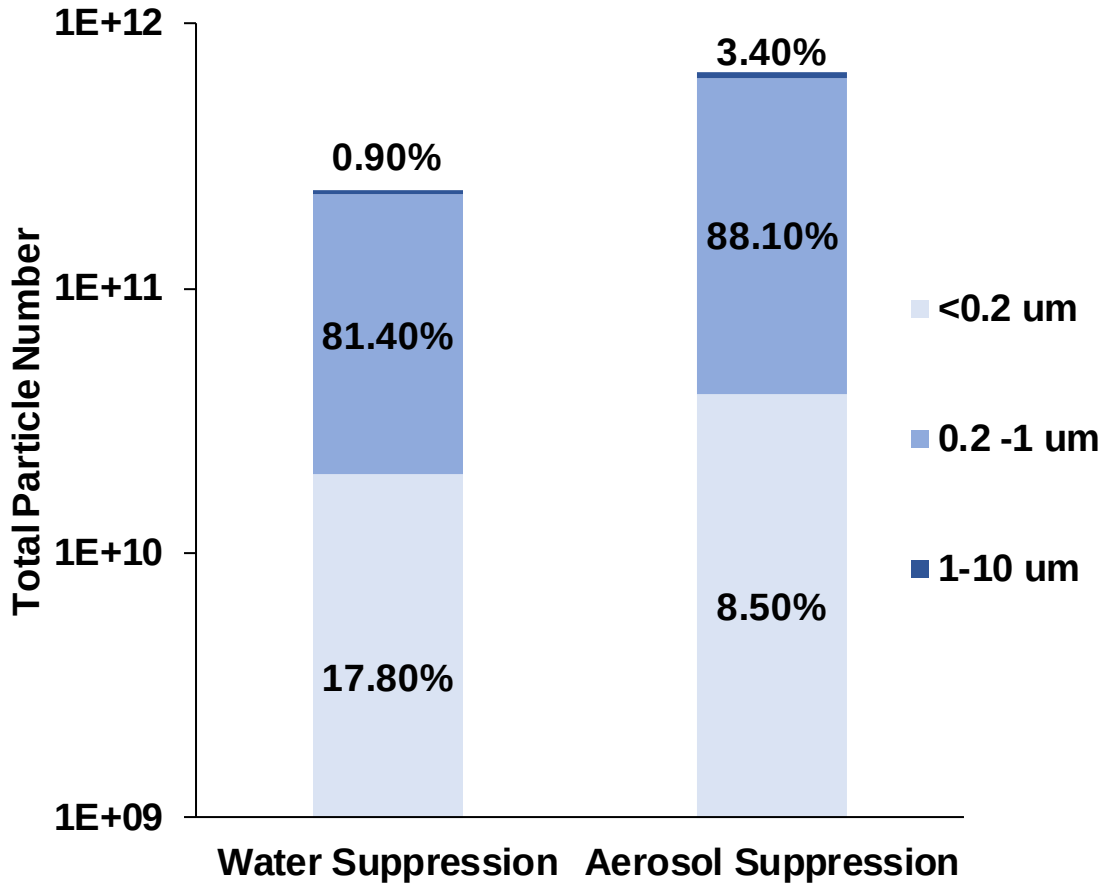
Test Matrix	
Test #	Suppression Method
1	Baseline – no suppression
2	Water
3	Aerosol

ve Real Time PSD



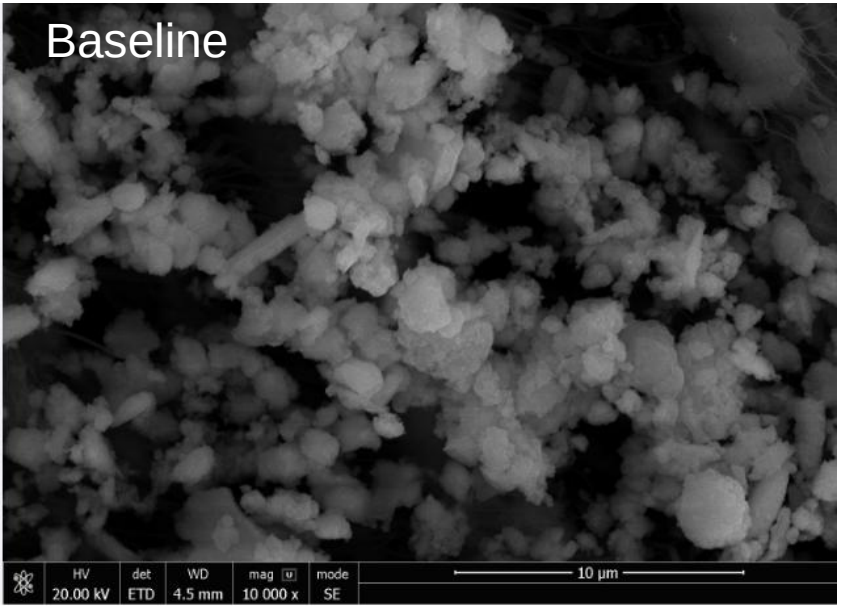
GMD ~360nm

Particle Number Emission Factors

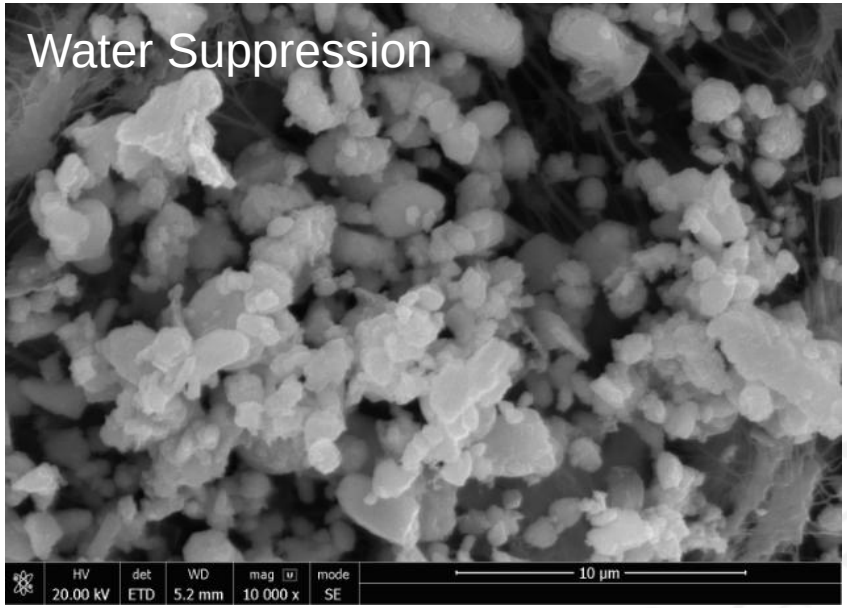


- Dominated by particles less than 1 um
- Aerosol Suppression introduced particles > 1um

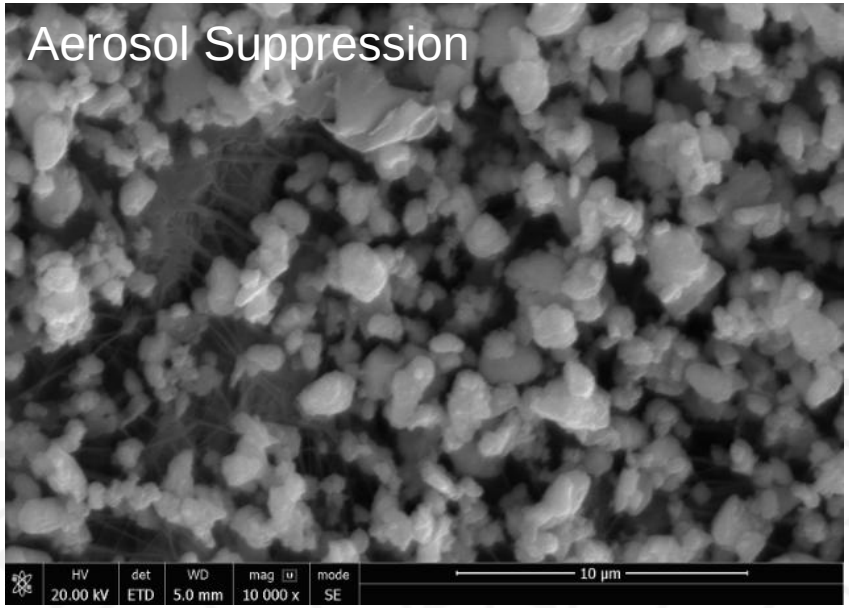
SEM



- Irregular aggregates
- Typically 0.9-2.5 um; up to 8 um

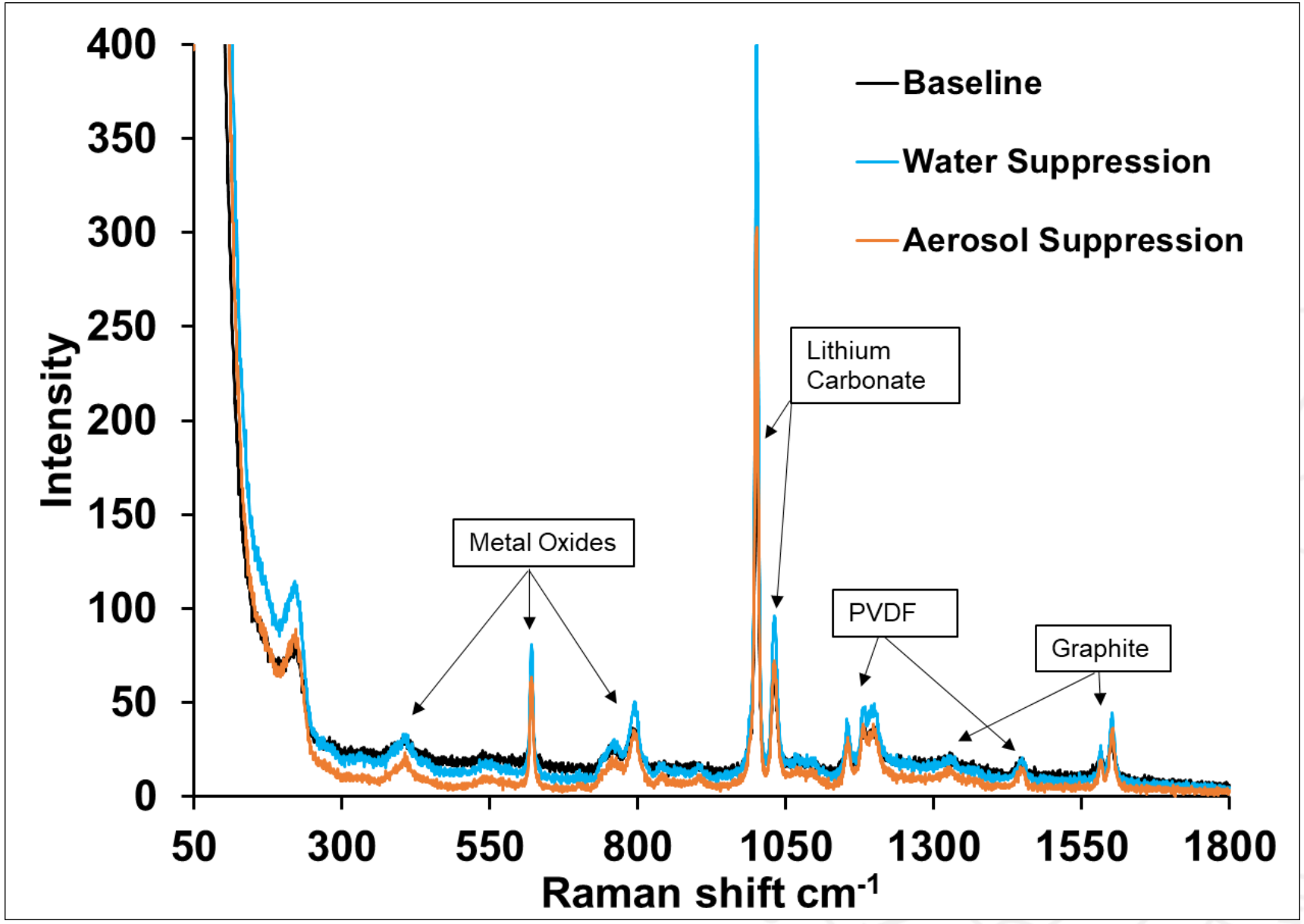


- Irregular aggregates & coalesced smooth particles
- Typically 0.9-2.3 um

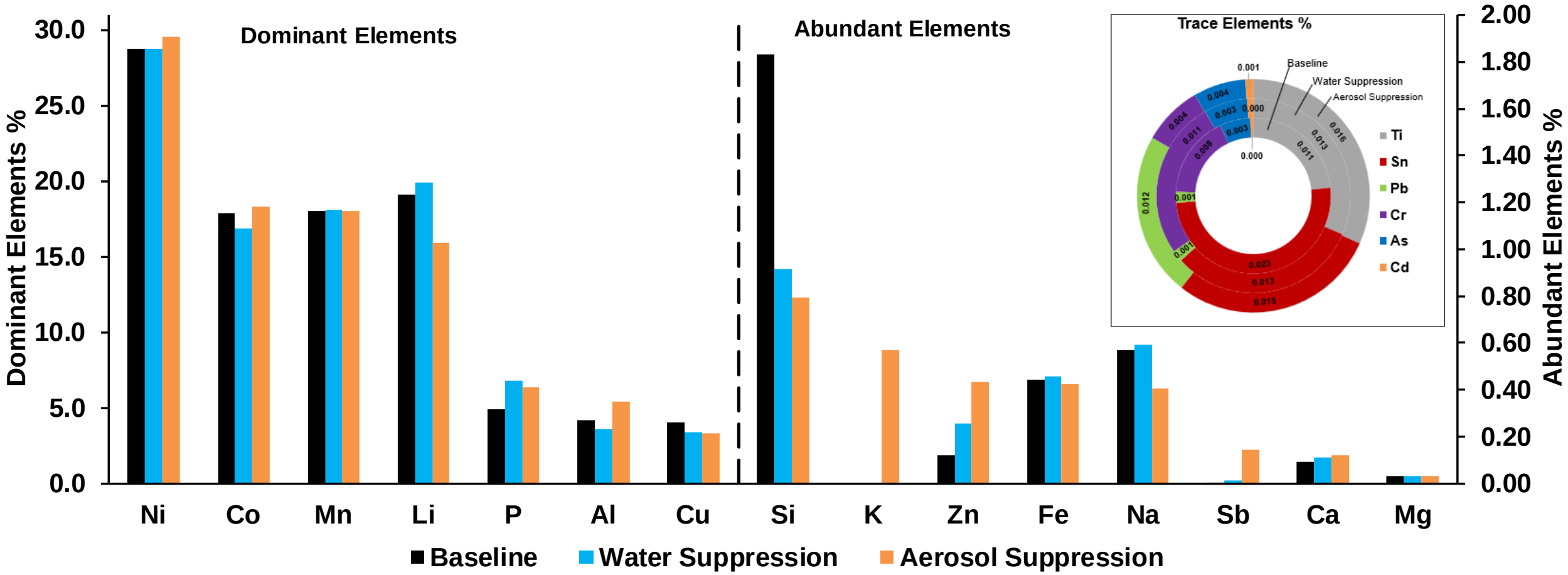


- More spherical; partially coalesced; smooth-surfaced
- Typically 0.6-2.2 um

Raman Spectroscopy

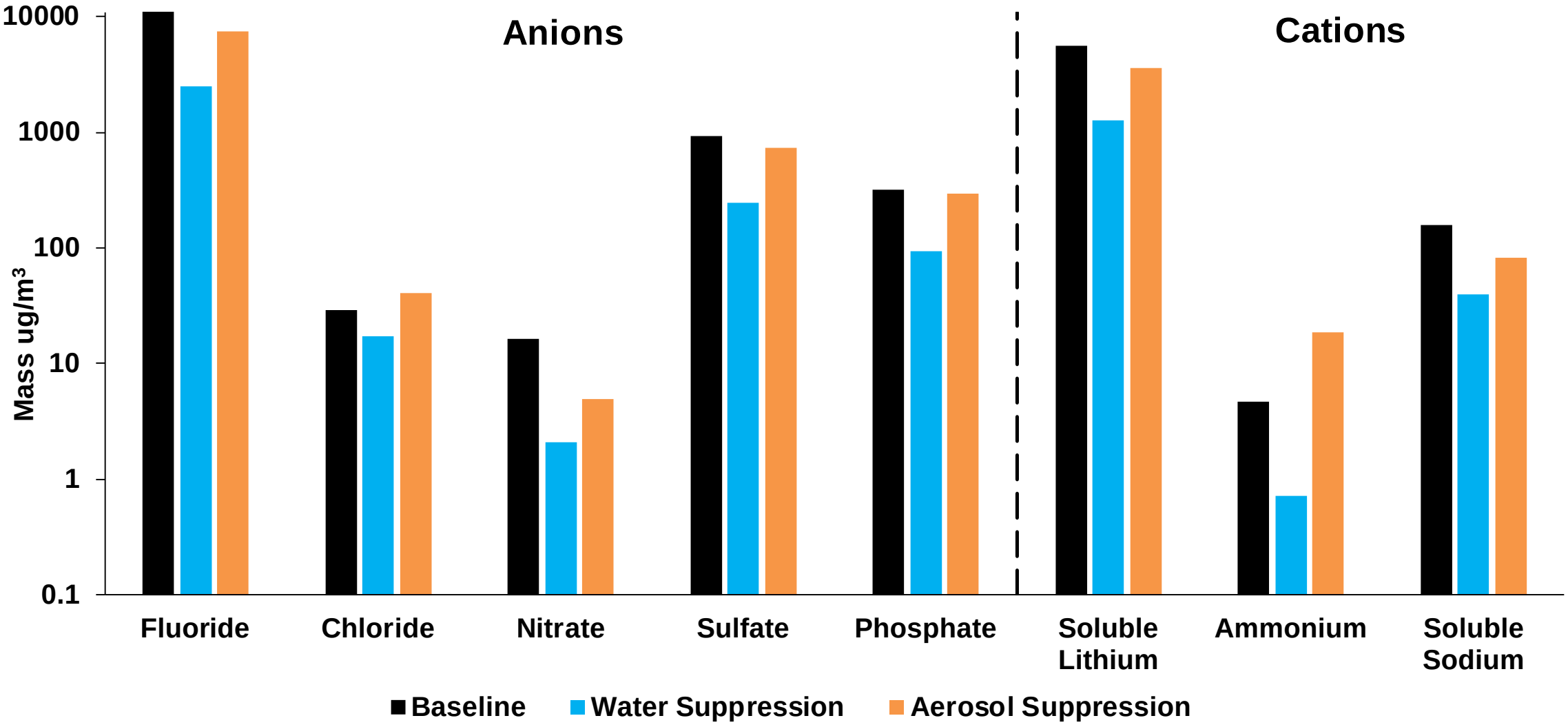


Metals and Trace Elements



- NMC cathode
- K based aerosol suppressant
- Traces of Cr

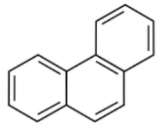
Ions

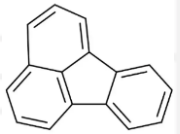

Anions
Cations
10000
1000
100
10
1
0.1
Mass ug/m³
Fluoride
Chloride
Nitrate
Sulfate
Phosphate
Soluble Lithium
Ammonium
Soluble Sodium
Baseline
Water Suppression
Aerosol Suppression

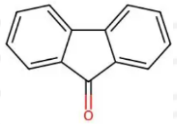
Polycyclic Aromatic Hydrocarbons				
		Baseline	Water Suppression	Aerosol Suppression
Compound	Rings	ug/m^3		
EPA Priority PAHs				
Naphthalene	2	0.05	0.29	0.08
Acenaphthylene	3	0.10	28.75	1.47
Acenaphthene	3	0.00	1.51	0.07
Fluorene	3	0.24	30.40	2.32
Phenanthrene	3	9.98	92.62	31.41
Anthracene	3	2.14	28.27	7.32
Fluoranthene	4	10.09	36.29	17.93
Pyrene	4	7.06	27.36	12.75
Chrysene	4	5.09	30.17	12.01
Benzo[b]fluoranthene	5	6.13	29.32	12.90
Benzo[k]fluoranthene	5	1.26	8.26	3.28
Benzo[a]pyrene	5	2.66	13.02	4.79
Dibenz[a,h]anthracene	5	0.72	5.17	1.77
Benzo[ghi]perylene	5	2.82	15.59	5.97
Indeno[1,2,3-cd]pyrene	6	2.06	11.17	4.41
Dominant Unsubstituted PAHs				
Benzo[c]phenanthrene	4	1.85	12.60	4.43
Benzo[e]pyrene	5	2.22	11.74	5.12
Coronene	7	1.28	7.49	2.14
Dominant Oxygenated PAHs				
Dibenzofuran	3	0.10	27.26	2.34
9H-Fluoren-9-one	3	3.43	38.39	15.55
1H-Phenalen-1-one	3	3.92	36.55	12.99
Dominant Substituted PAHs				
Phenanthrene, 9-methyl	3	0.72	10.92	2.03
Naphthalene, 2-phenyl-	3	4.52	31.56	11.16
Total Oxygenated		13.51	150.10	58.48
Total Substituted		17.72	172.67	62.00
Total PAHs		103.01	785.10	264.71

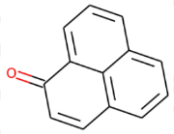
PAHs

- Water suppression total PAHs 3x higher than aerosol & 7.6x higher than baseline
- Oxygenated PAHs: 13-22%
- Substituted PAHS: 17-23%
- Most abundant PAHs:

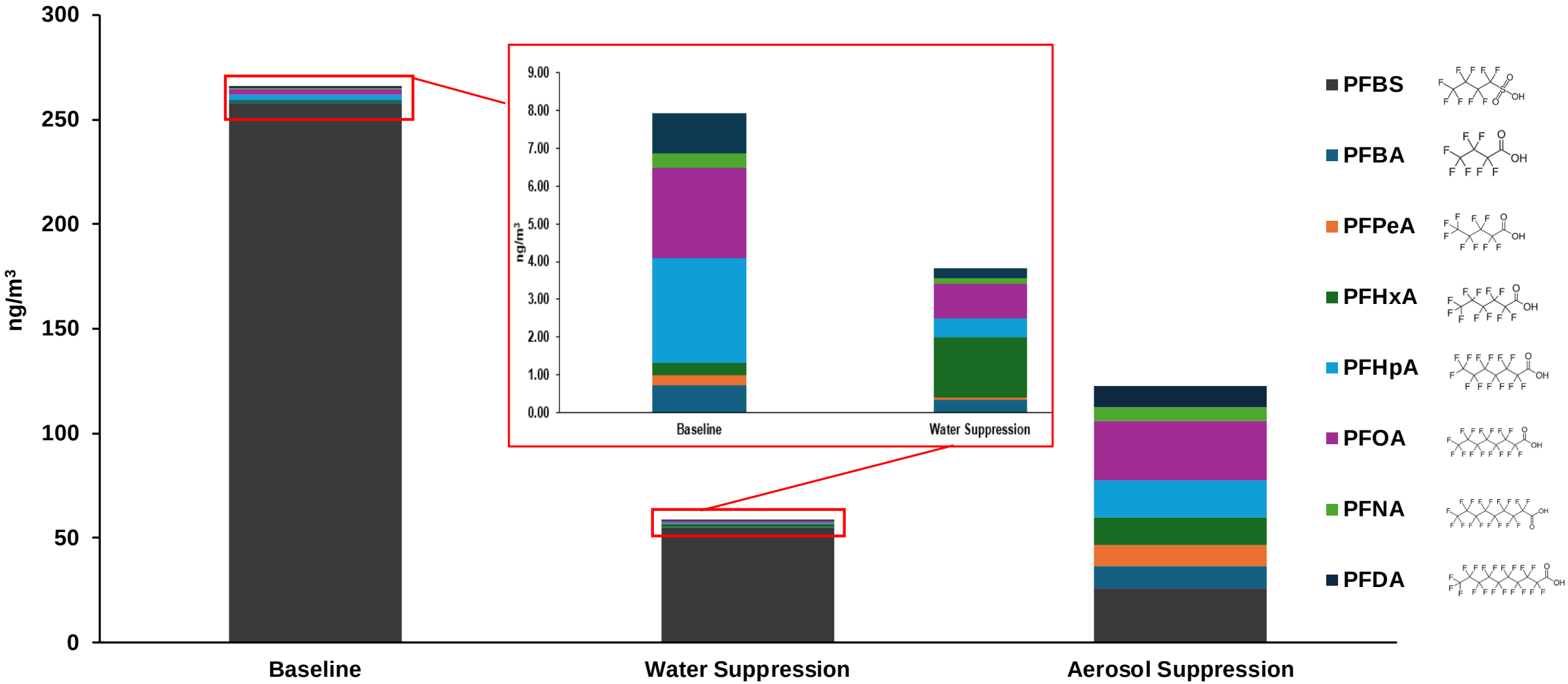
Phenanthrene 

Fluoranthene 

9H-Fluoren-9-one 

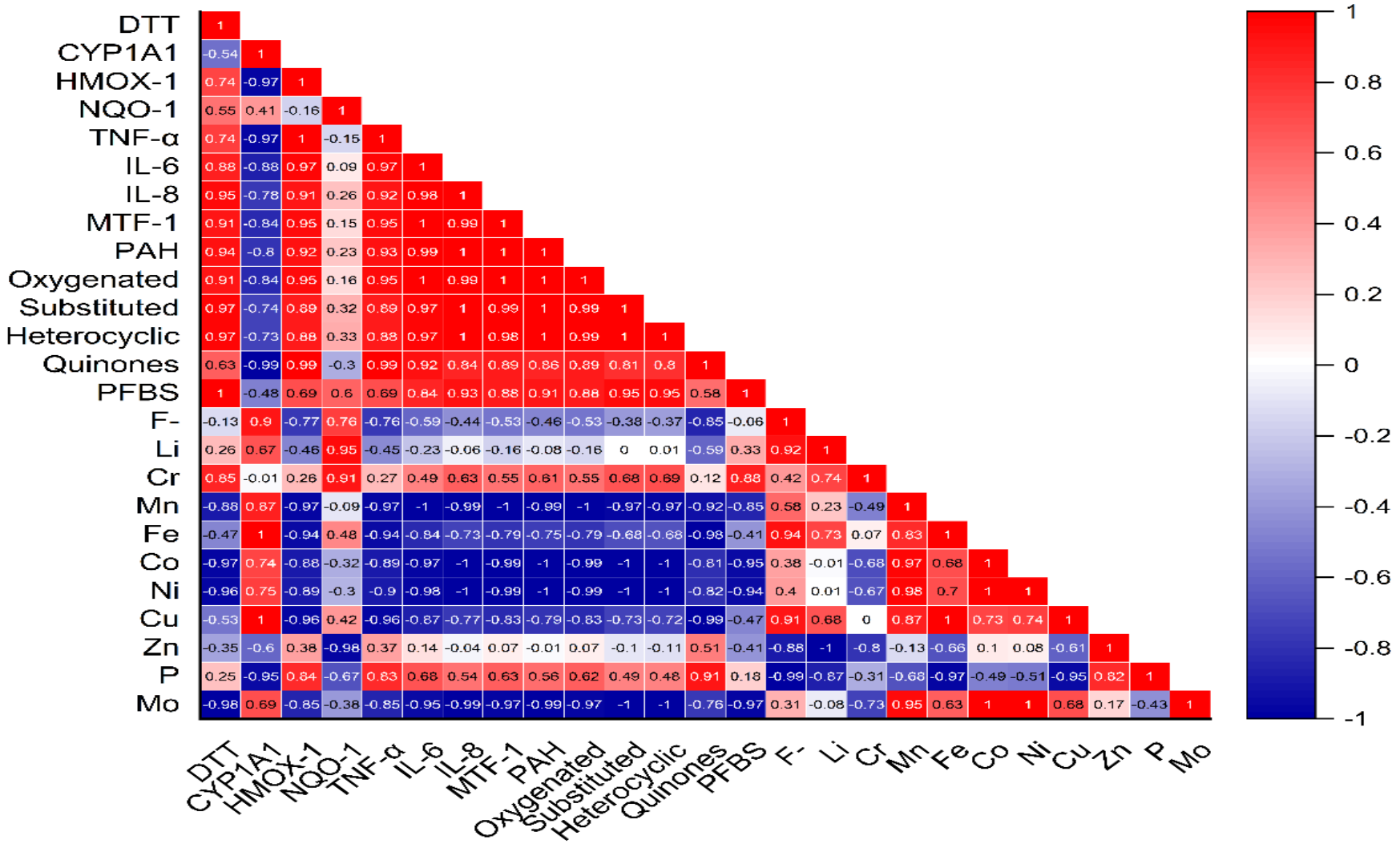
1H-Phenalen-1-one 

PFAS



Total PFAS: 268 ng/m^3 59.9 ng/m^3 132.4 ng/m^3

Correlation Analysis



Notable Correlations:

1. Positive correlation between DTT and quinones/ oxygenated PAHs/ gene expression for oxidative stress and metabolism

2. Negative correlation between transition metals and DTT

3. Positive correlation between PFBS and inflammatory gene markers

Summary

- Investigated physiochemical and toxicological properties of particulate emissions and the influence of water vs aerosol suppression
- Majority of particles were <1um
- Metals dominated by Ni, Li, Mn, Co, P, Al; dominate ions were fluoride and phosphate
- Water suppression test has substantially higher PAH emissions
- PFAS concentration were elevated for all tests, with short-chain PFAS: PFBS, PFOA, & PFHpA
- DTT assays and gene expression indicated that toxicity is governed by a complex mixture of combustion products and not a single component

Questions?

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