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AI

Estimating Respirable Silica Concentration from CPDM Samples Using FTIR Analysis: Results from Lab and Field Samples

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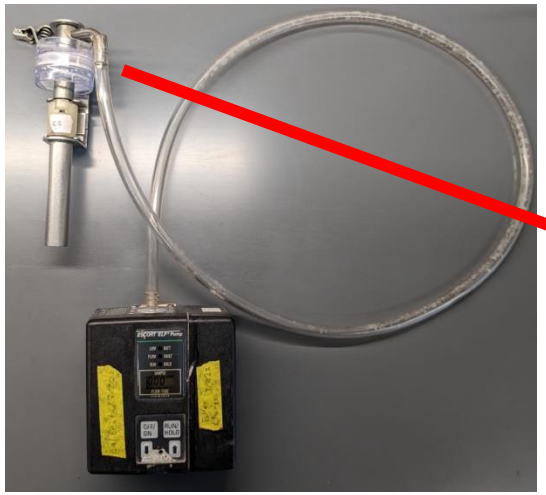
Mining and Minerals Engineering
VIRGINIA TECH

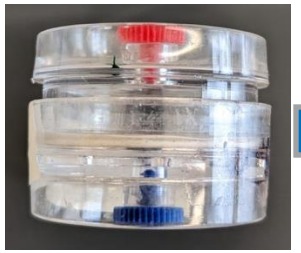
Background

Respirable Dust Collection and Analysis - Past

Respirable Dust Collection



CMDPSU (10mm Dorr-Oliver Cyclone + ELF Pump)



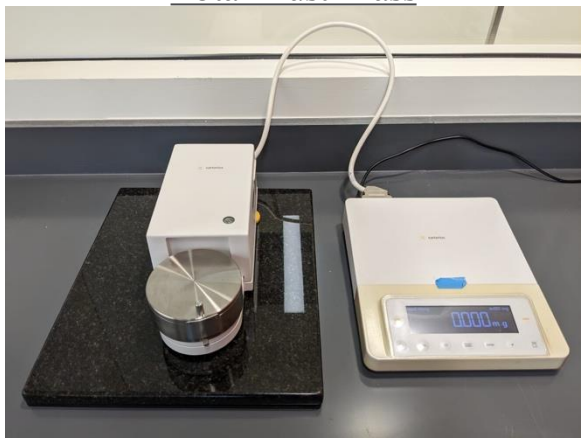
37mm PVC Filter

ANALYSIS

Silica Dust Mass

MSHA P7 Method with Infrared Spectrometer*

Total Dust Mass



Scale to Measure Pre-Post Sampling Weights

* Perkin-Elmer Model 621 Grating Infrared Spectrophotometer from https://digital.sciencehistory.org/works/r207tq060

Continuous Personal Dust Monitors (CPDMs)

- MSHA's new dust rule adopted in 2014 requires the use of CPDMs for monitoring total respirable coal mine dust (RCMD) exposure to underground miners

- The CPDM is widely used, but does not enable analysis of specific dust constituents, such as respirable crystalline silica (RCS)

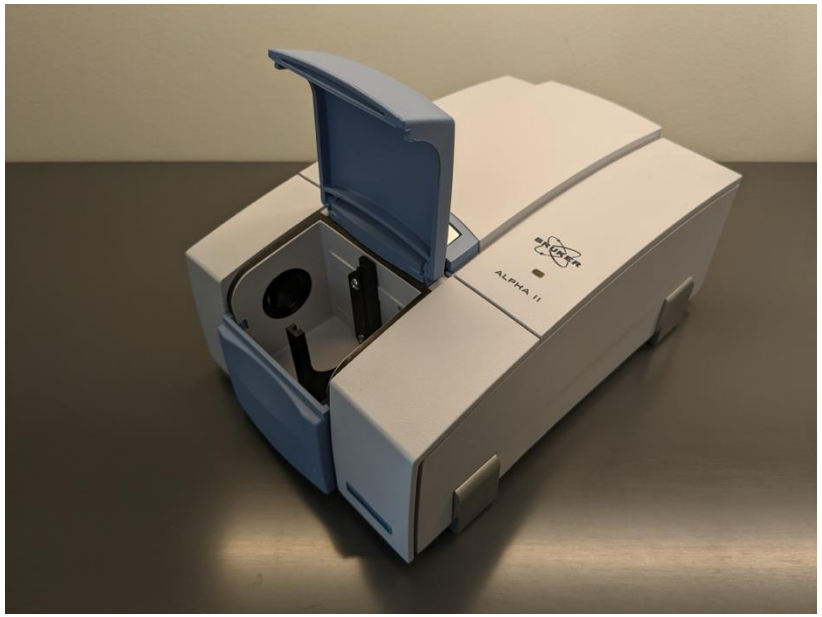
Thermo Scientific Personal Dust Monitor (PDM 3700)

Source: Thermo Scienitific Personal Dust Monitor Model PDM3700 Manual

Portable, Direct-on-Filter Fourier Transform Infrared (FTIR) Spectrometer

- This FTIR spectrometer can be used for non-destructive testing of 37mm Polyvinyl Chloride (PVC) filters, allowing for end-of-shift RCS monitoring for mine sites

10mm Dorr-Oliver Cyclone + ELF Pump

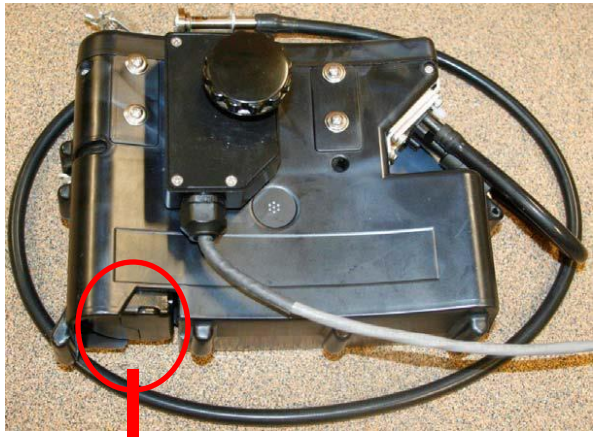


Bruker Optics Alpha II FTIR Spectrometer

- Finding a way to use the CPDM's internal filter to allow for analysis by FTIR onsite could allow mine operators to increase their silica monitoring capabilities

Indirect Analysis is the Topic of this Investigation

CPDM*



Mass Transducer

CPDM's TEOM Filter

Made of borosilicate fibers

Dust Recovery And Redeposition

FTIR Spectrometer

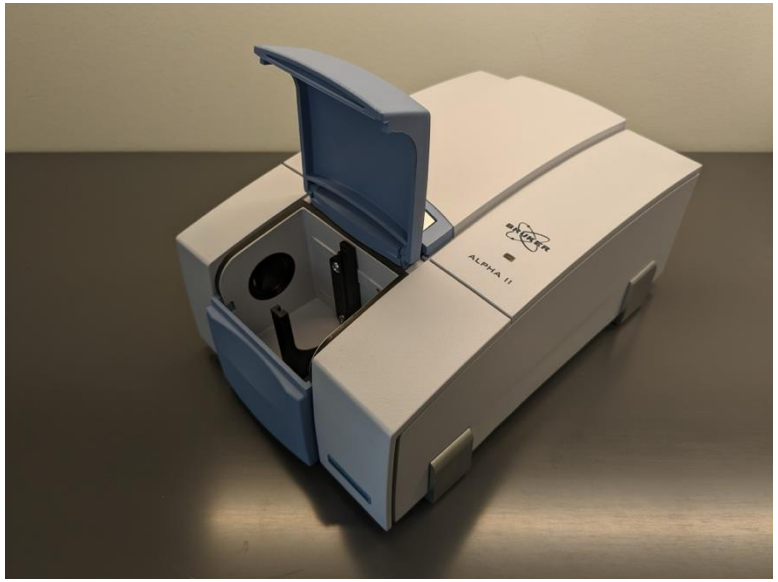
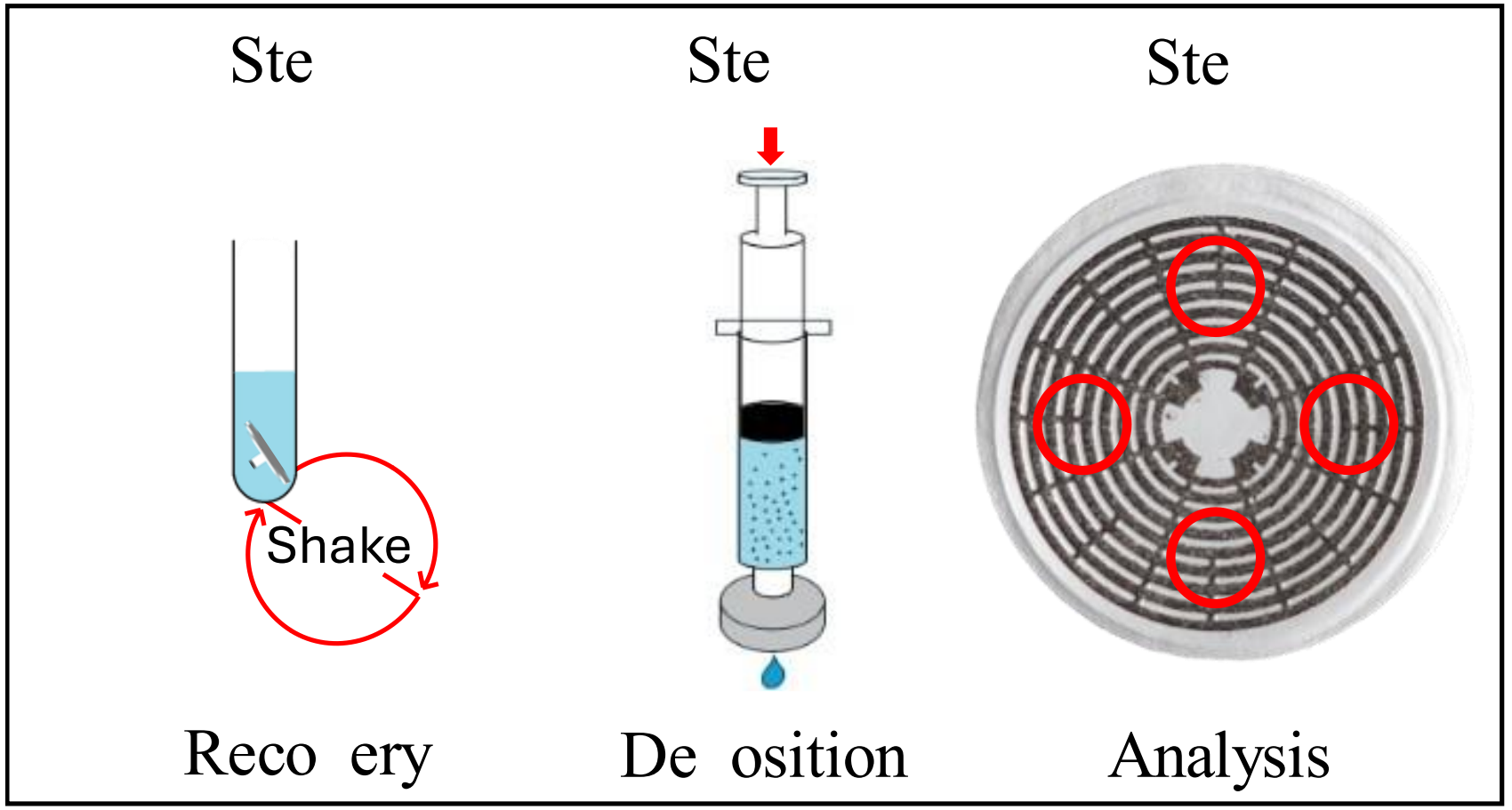


*Image from Thermo Scienitific Personal Dust Monitor Model PDM3700 Manual

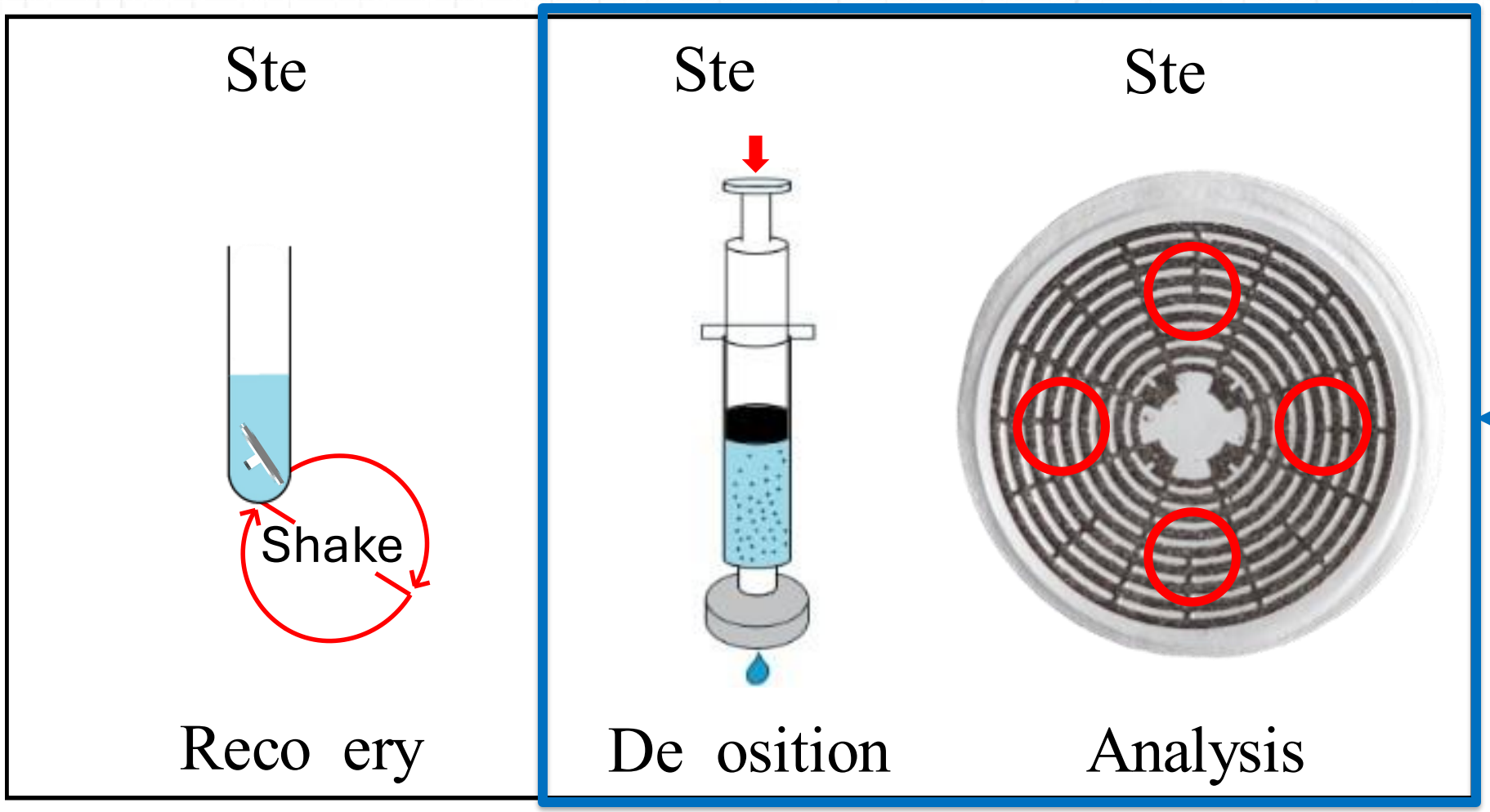
Envisioned Methodology



Part 1 - Dust Deposition and Analysis

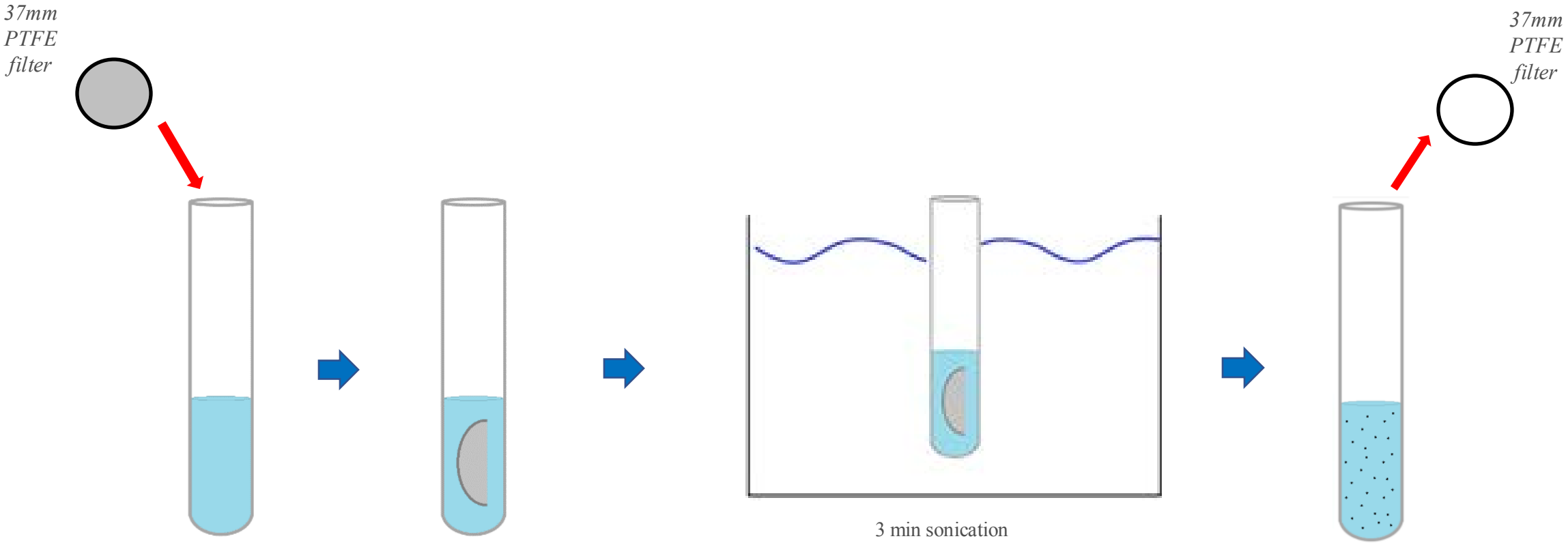
Paper Title	Status
Toward rapid silica analysis of CPDM samples: deposition of recovered dust and analysis by FTIR	Published in the Journal of Occupational and Environmental Hygiene, 2024

Investigation Overview – Part 1

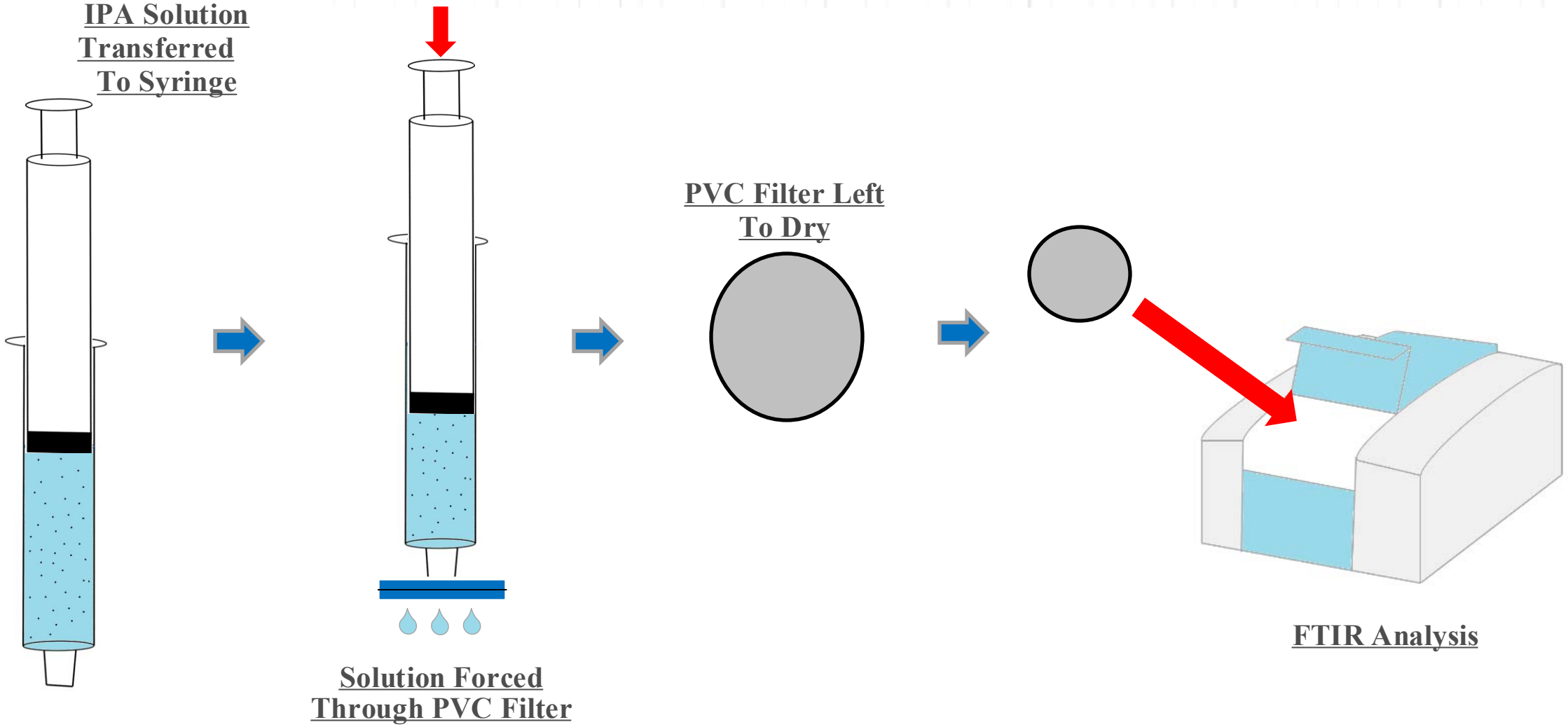


Methods, Dust Recovery

Dust Recovery – Wet Method

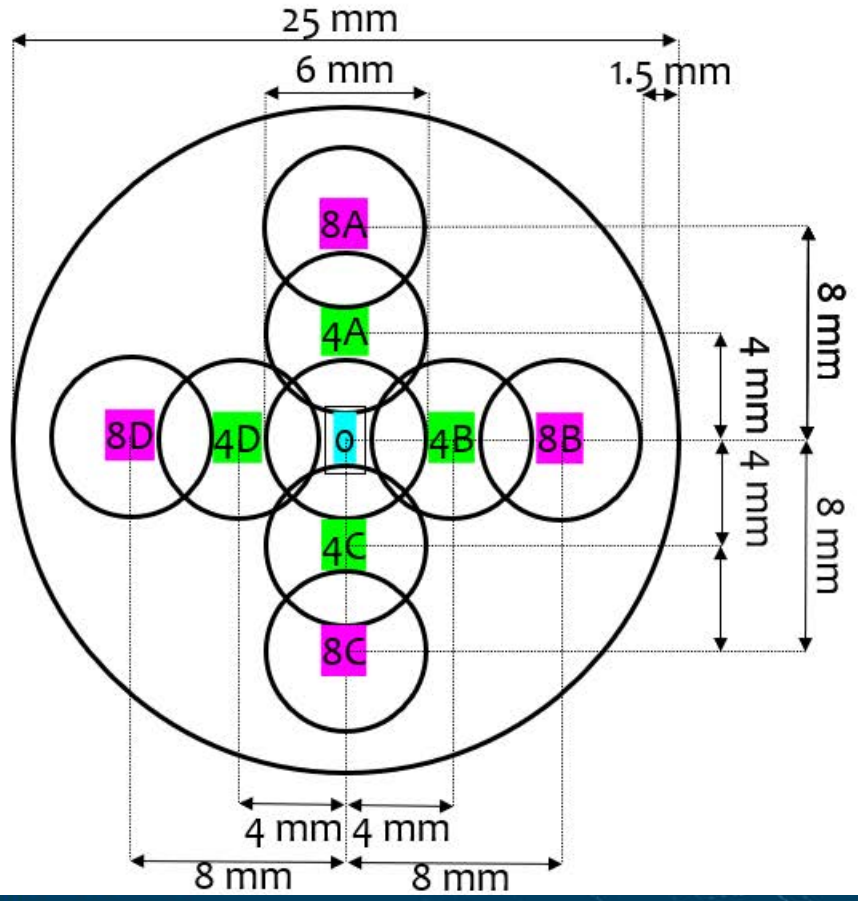


Methods, Dust Redeposition

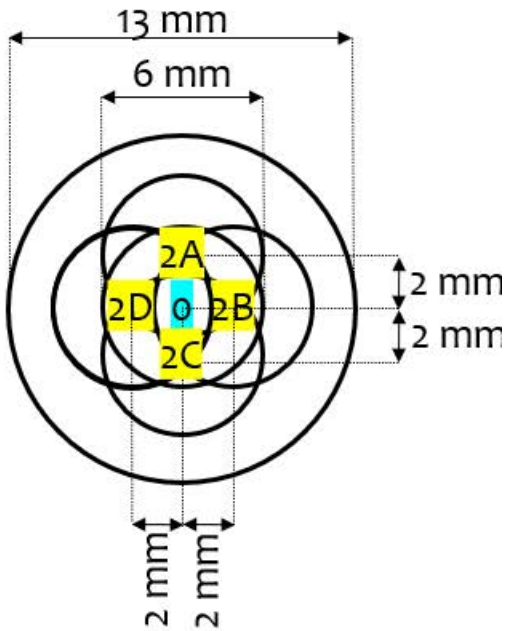


Scanning Locations

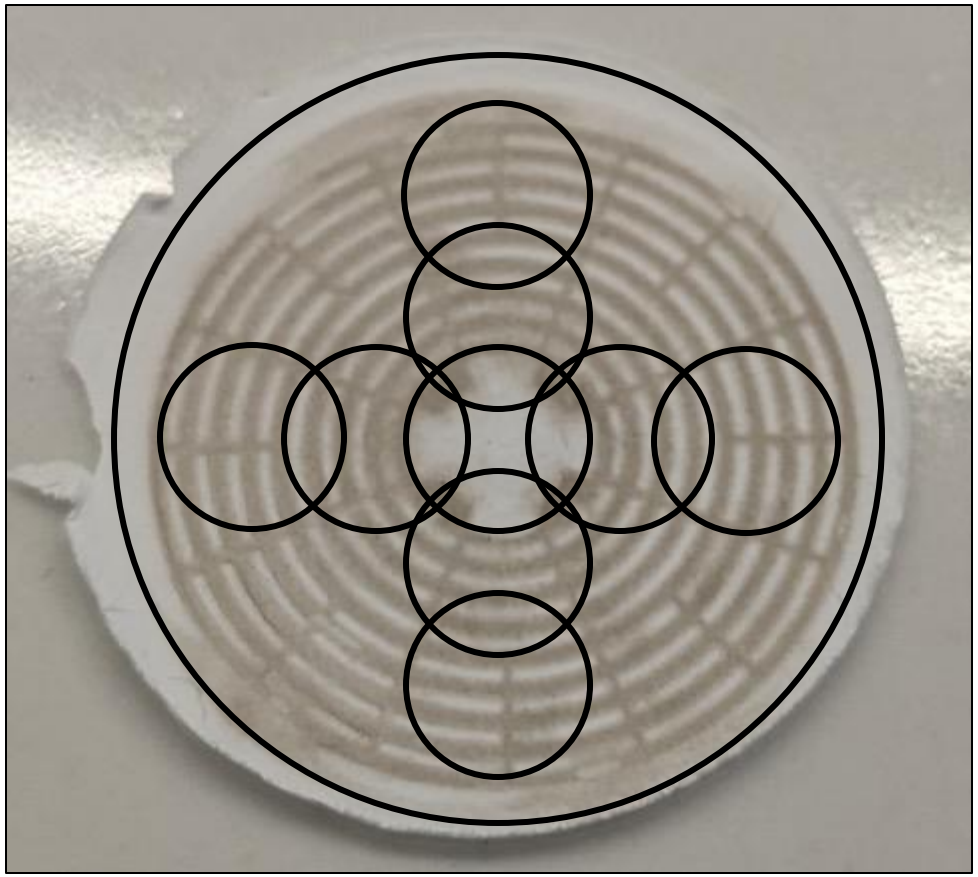
25 mm PVC Filter

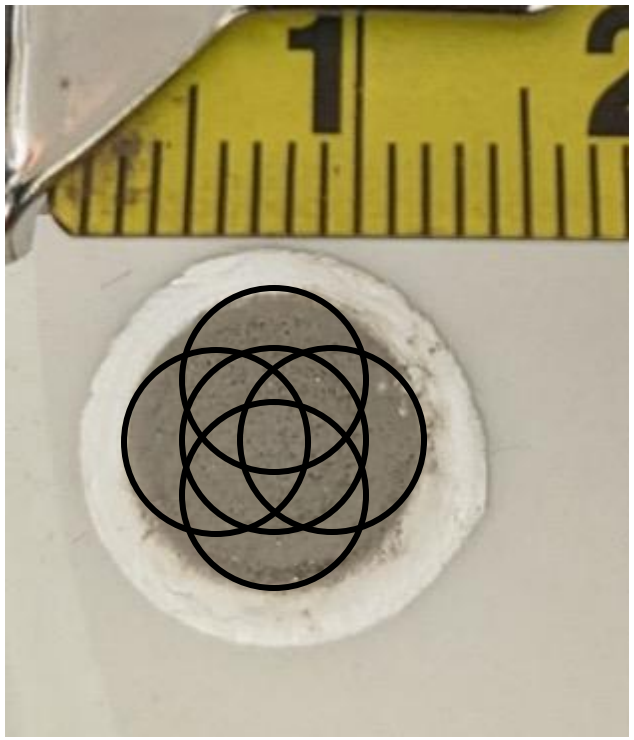


13 mm PVC Filter

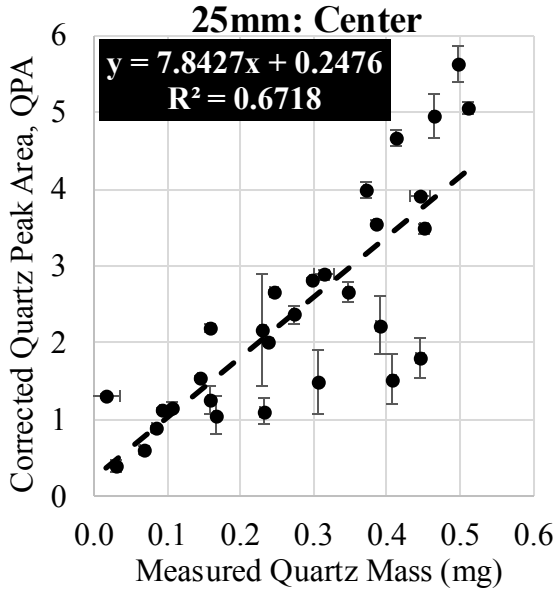


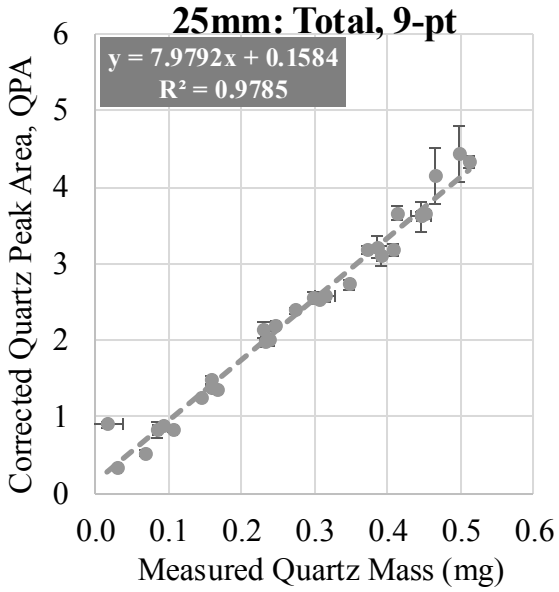
Syringe Method Deposition Pattern

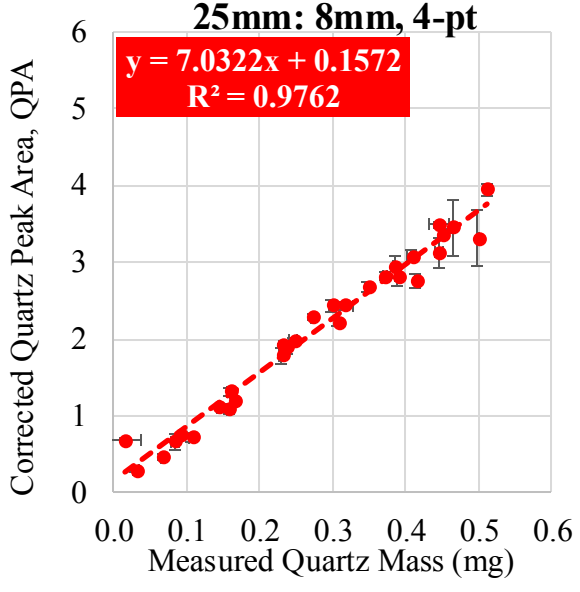


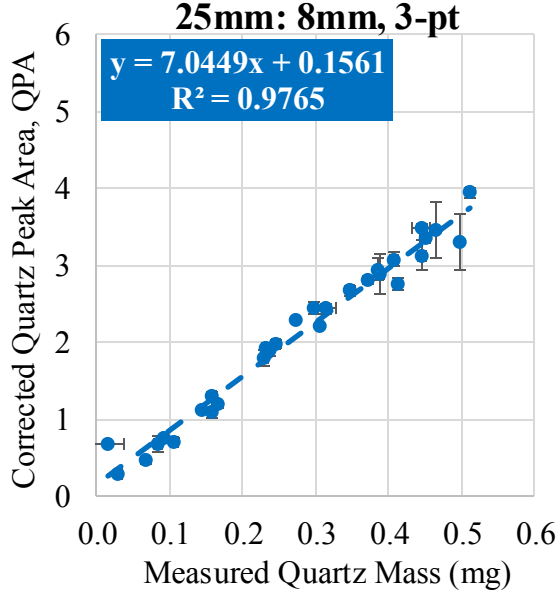


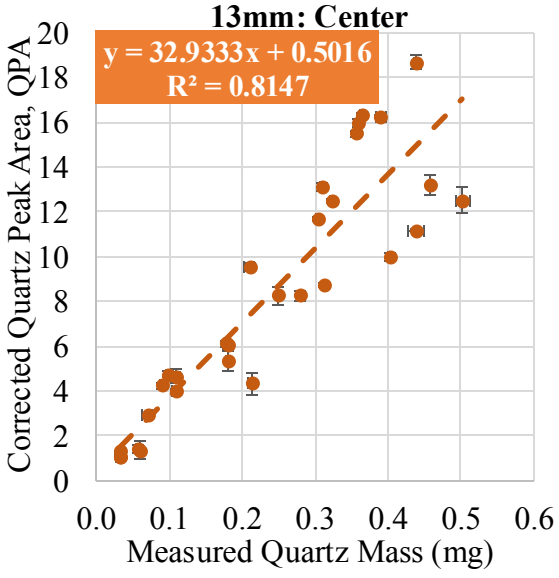
MIN-U-SIL 5 Quartz Peak Areas (QPA) versus Measured Quartz Mass

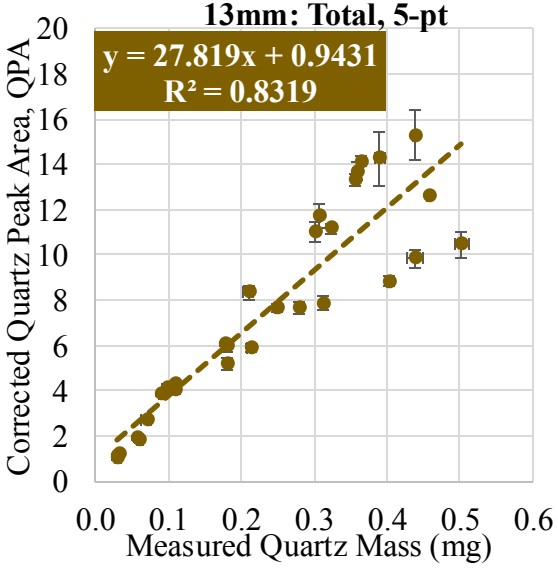


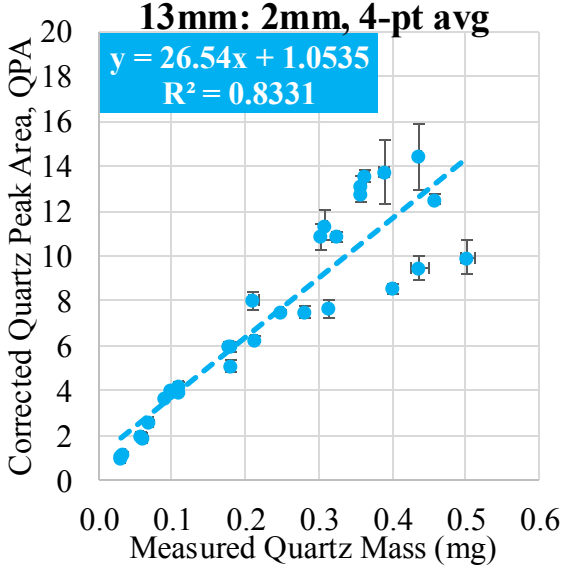


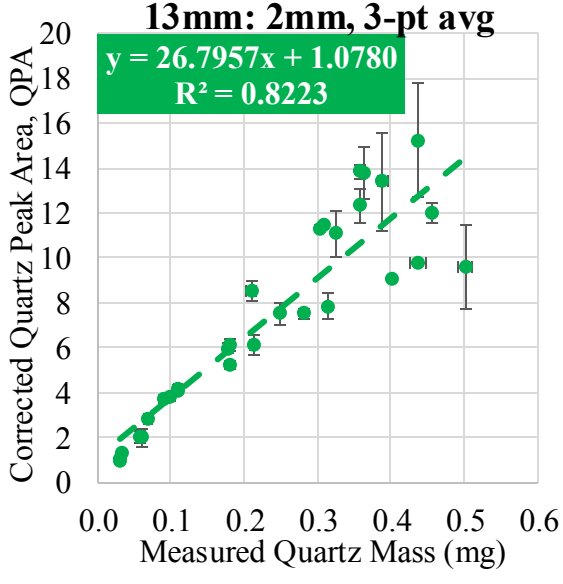








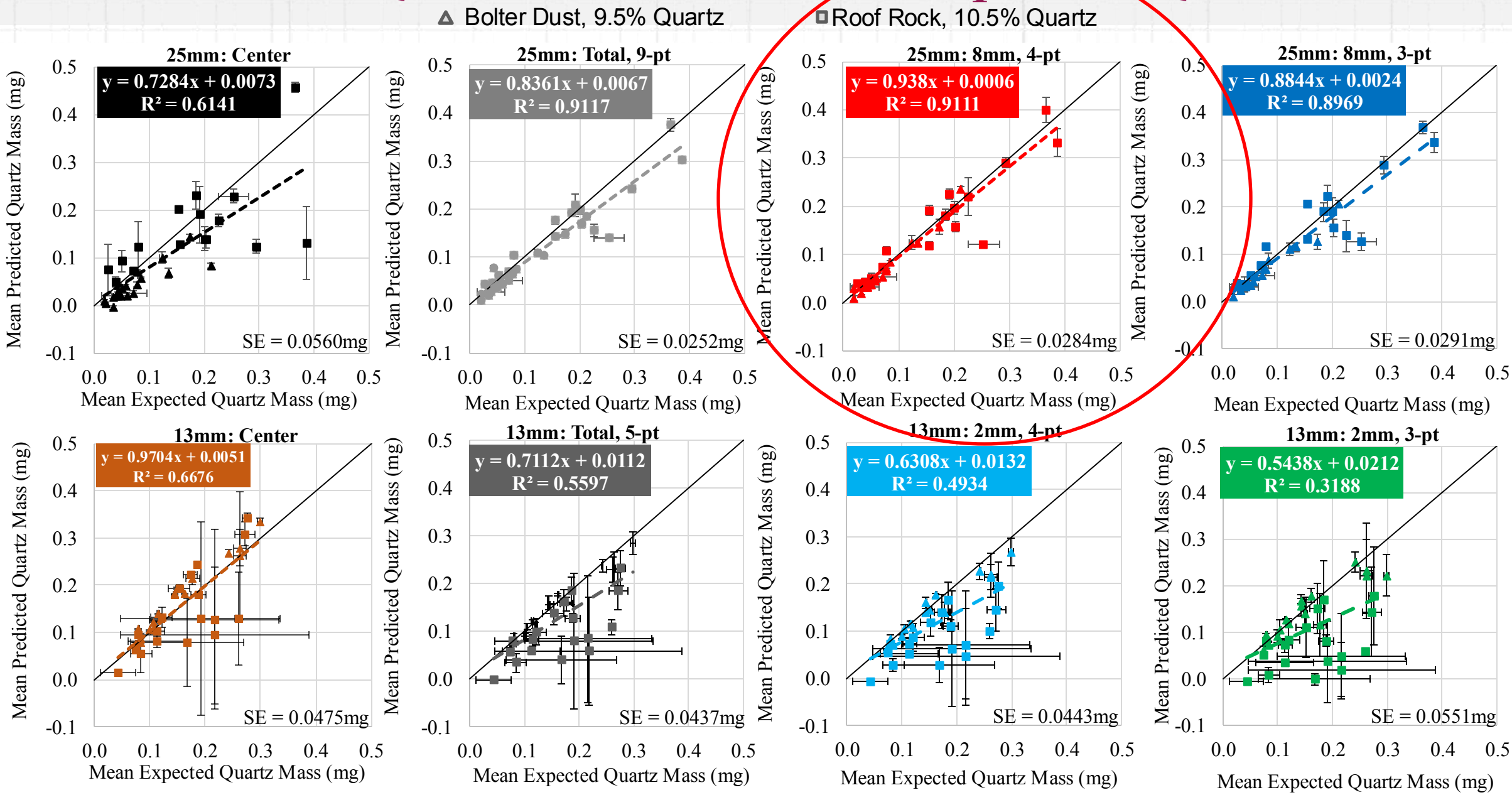




QPA-to-Quartz mass calibration factors

Filter Size	Scanning Pattern	Q_{pred} Equation
25-mm	Center	$\frac{QPA - 0.2476}{7.8427}$
25-mm	4mm, 4-pt	$\frac{QPA - 0.1372}{8.9602}$
25-mm	8mm, 4-pt	$\frac{QPA - 0.1572}{7.0322}$
25-mm	Total, 9-pt	$\frac{QPA - 0.1584}{7.9792}$
25-mm	Center+4mm, 5-pt	$\frac{QPA - 0.1593}{8.7367}$
25-mm	Center+8mm, 5-pt	$\frac{QPA - 0.1753}{7.1943}$
25-mm	4mm, 3-pt	$\frac{QPA - 0.1241}{8.9291}$
25-mm	8mm, 3-pt	$\frac{QPA - 7.1633}{0.1677}$
13-mm	Center	$\frac{QPA - 0.5016}{32.9333}$
13-mm	2mm, 4-pt	$\frac{QPA - 1.0535}{26.5403}$
13-mm	Total, 5-pt	$\frac{QPA - 0.9431}{27.819}$
13-mm	2mm, 3-pt	$\frac{QPA - 1.0781}{26.7954}$

Mean Predicted Quartz Mass vs Mean Expected Quartz Mass



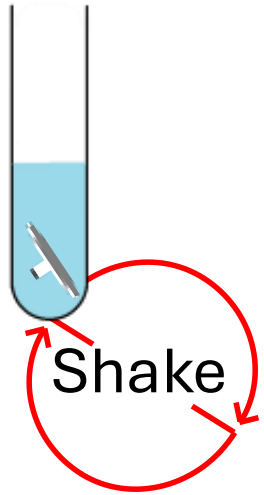
Part 2 – Evaluating Recovery Methods

Paper Title	Status
Toward rapid silica analysis of CPDM samples: a study of dust recovery and quartz estimation using lab and field samples	Accepted and awaiting publication to the Journal of Occupational and Environmental Hygiene

Investigation Overview – Part 2

Part 2

Ste



Reco ery

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De osition

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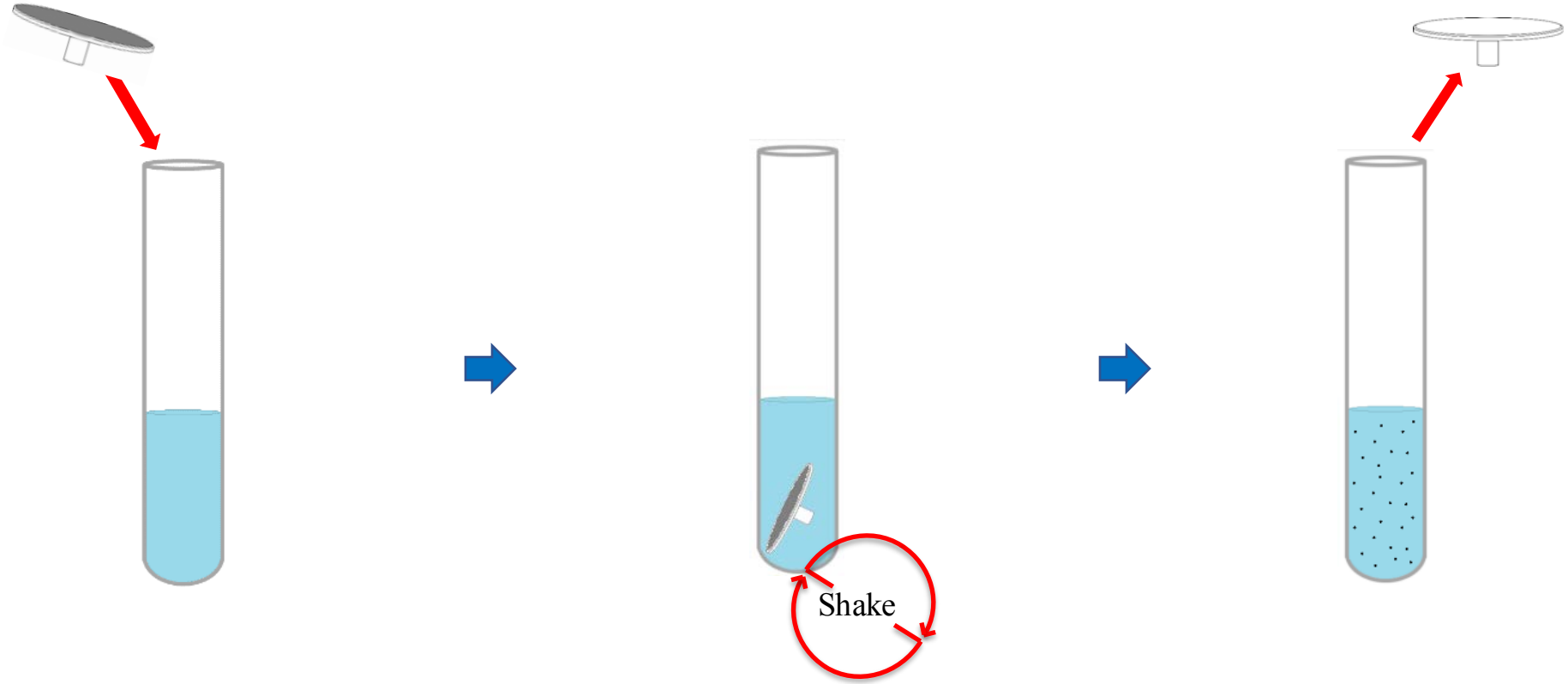
Analysis

Part 1

Methods, Dust Recovery

15mm
CPDM
Filter

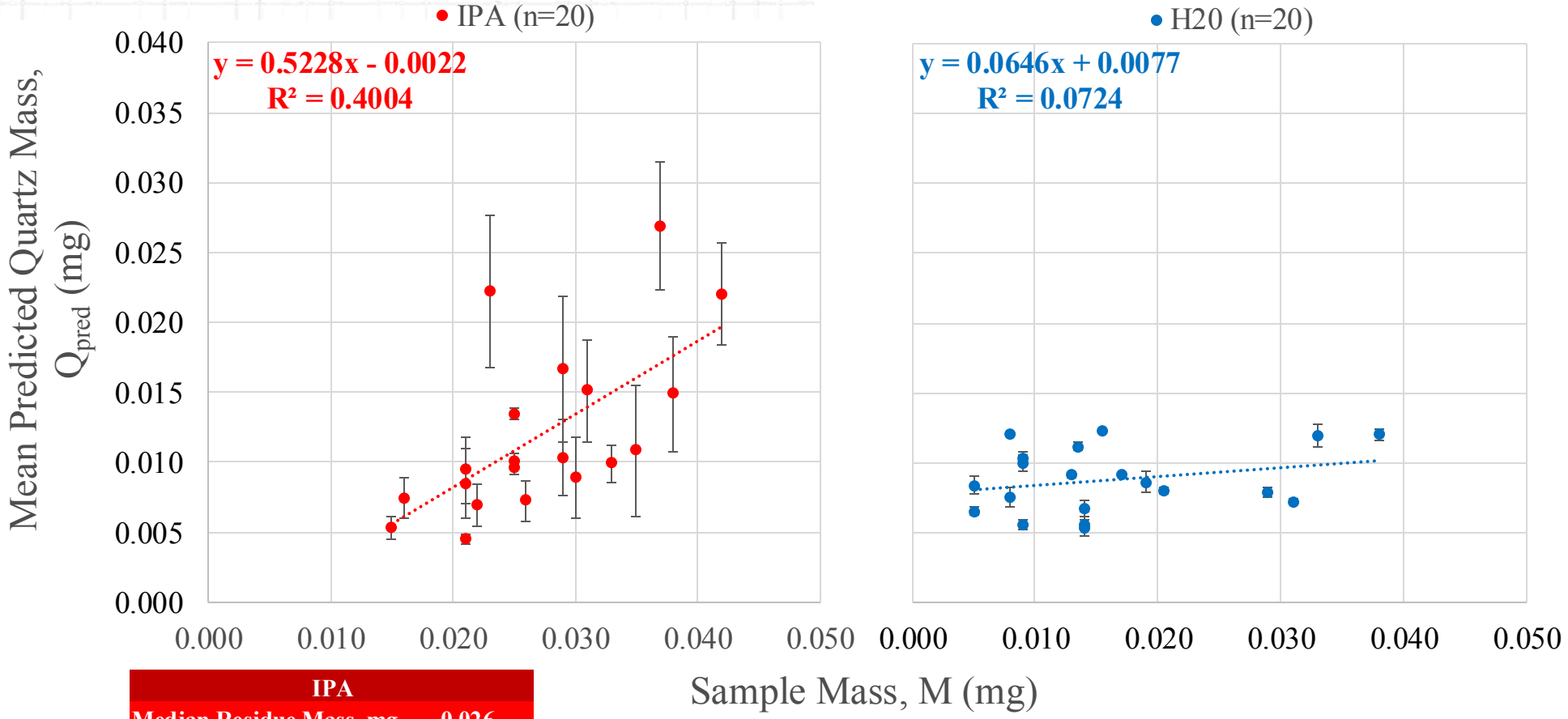


CPDM Samples

- CPDM Samples Tested in this study:
  - 40x Blank CPDM Filters – for baseline correction
  - 40x Spiked CPDM Filters – measure impact of correction
  - 34x Field CPDM Filters – evaluate recovery
    - 34 CPDM filter samples were collected in the field for analysis.

- Samples were tested with IPA or H2O to compare different recovery solutions

Blank CPDM Filter Samples

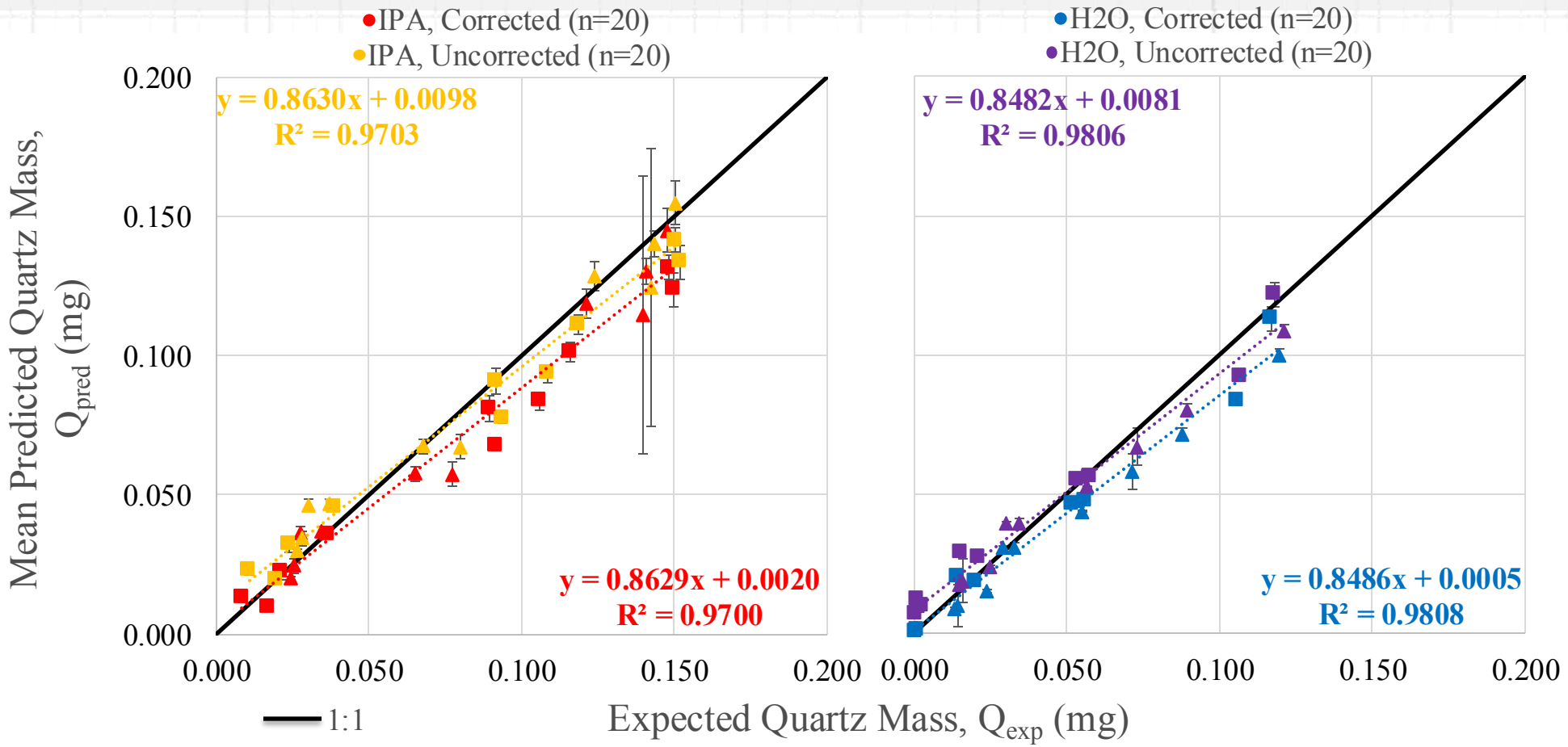


IPA	
Median Residue Mass, mg	0.026
Median Quartz Mass, mg	0.010
H20	
Median Residue Mass	0.014
Median Quartz Mass	0.009

$$M' = M - M_{blank}$$

$$Q_{pred}{}' = Q_{pred} - Q_{pred\_blank}$$

Spiked CPDM Filter Samples



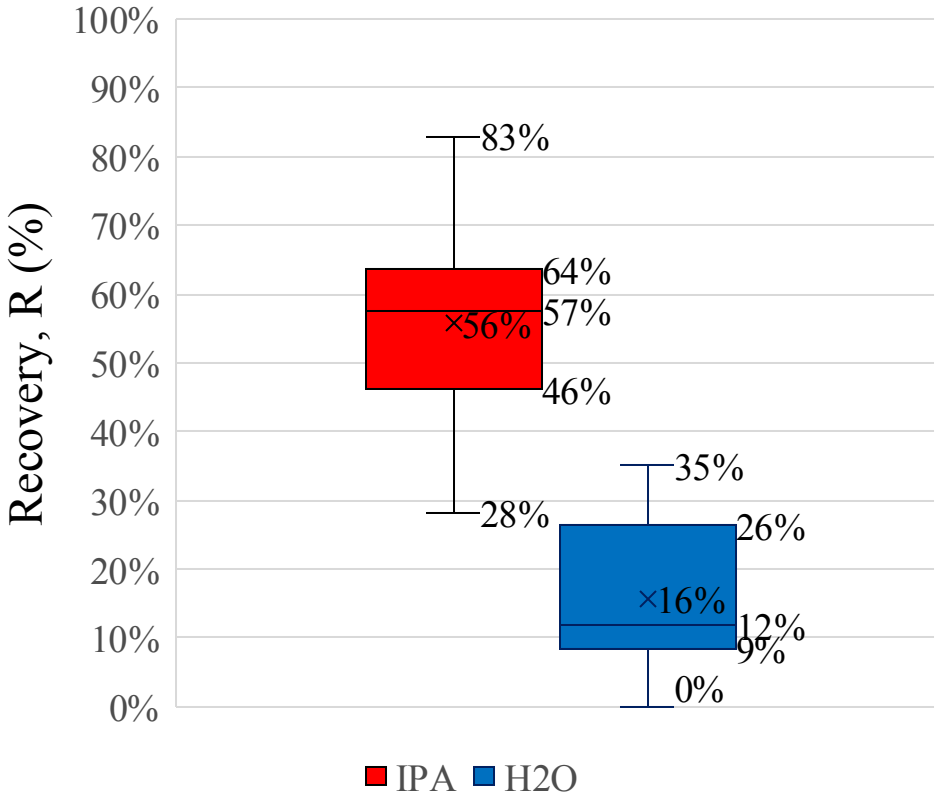
$$Q_{exp} = M * P_Q$$

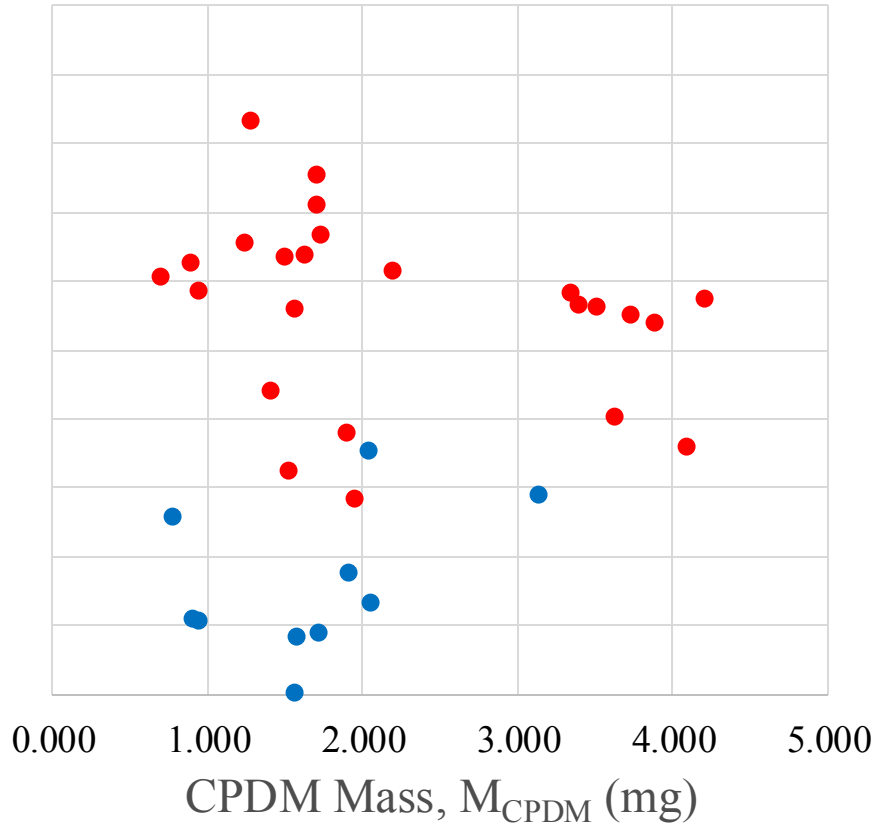
Where M is the sample mass and P_Q is the percent quartz.

Bolter Dust, P_Q = 9.5% Quartz

Roof Rock, P_Q = 10.5% Quatz

Field CPDM Samples, Dust Recovery

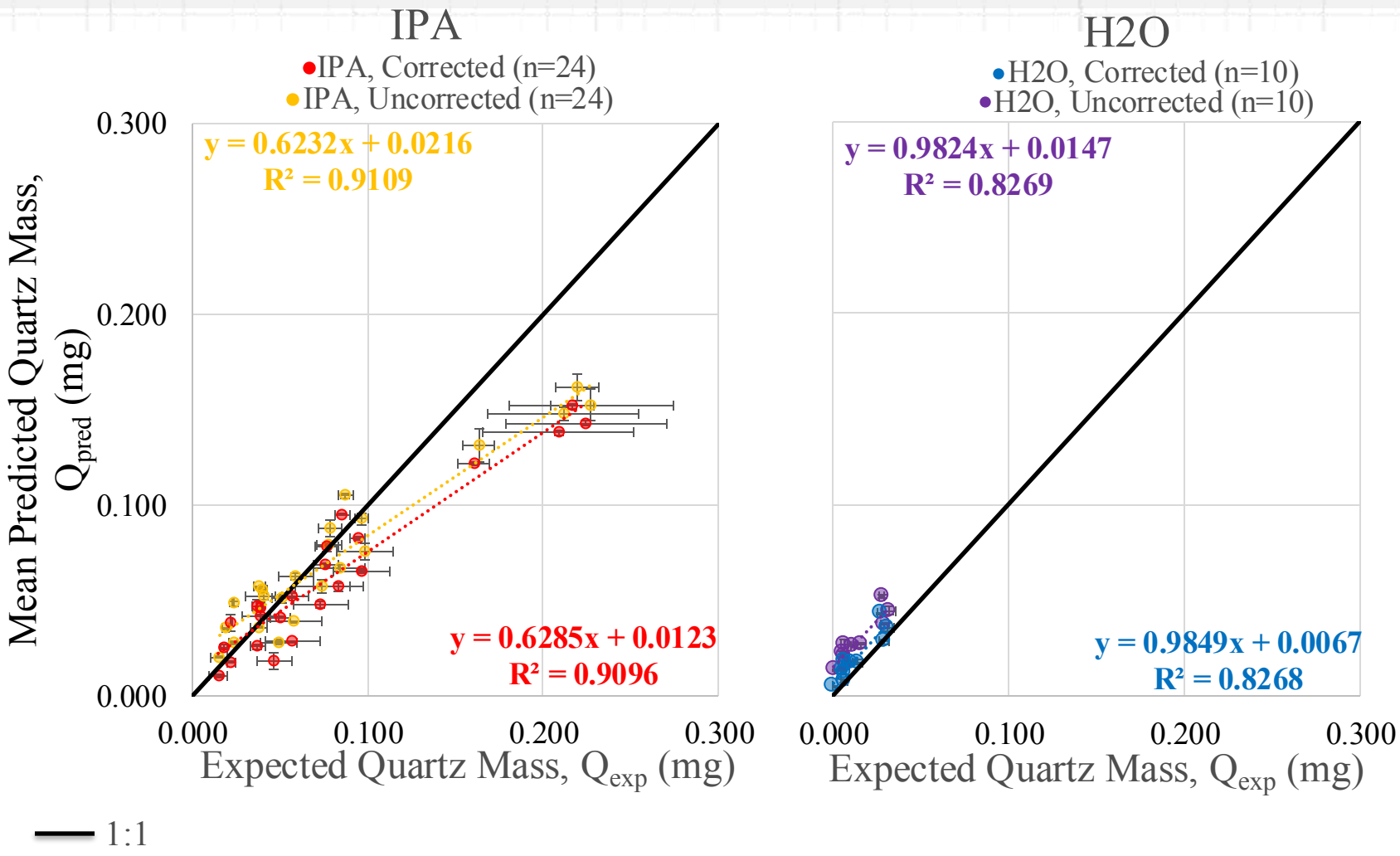




$$R = \frac{M'}{M_{CPDM}} \times 100\%$$

Where R is recovery, M' is the corrected sample mass, and M_{CPDM} is the mass of the dust on the filter.

Field CPDM Samples, Predicted versus Expected Quartz Masses



Conclusions

- These studies developed and evaluated a three-step method to recover, deposit, and analyze dust from CPDM filter samples for Quartz determination by FTIR.
- Results indicated that reco ery of the dust on the CPDM filter's was oor.
  - This can be remedied in the lab by taking a pre and post weight of the CPDM filter, but this often is not possible in the field.
- The method's ability to redict quartz mass decreased as a function of total sample mass, but the method can still accurately measure quartz for lower mass samples.
- This method offers mine operators and researchers a practical approach to enhancing underground dust monitoring.

End

Questions?

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