Effect of Relative Humidity Hysteresis on Loading Characteristics of Air Intake Filter Media by Hygroscopic Salt Particles

Chenxing Pei, Qisheng Ou, and David Y.H. Pui
Particle Technology Laboratory, University of Minnesota

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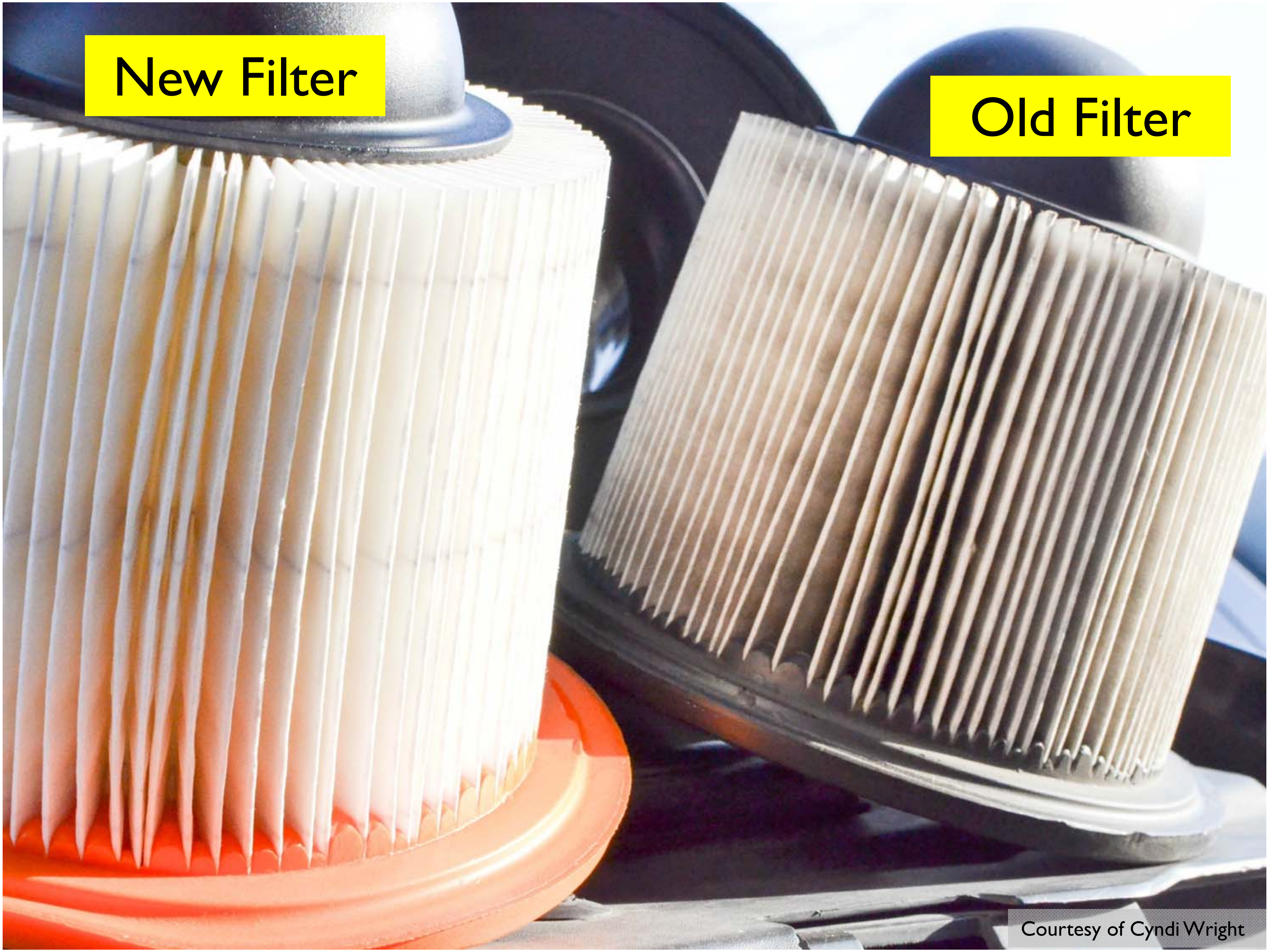
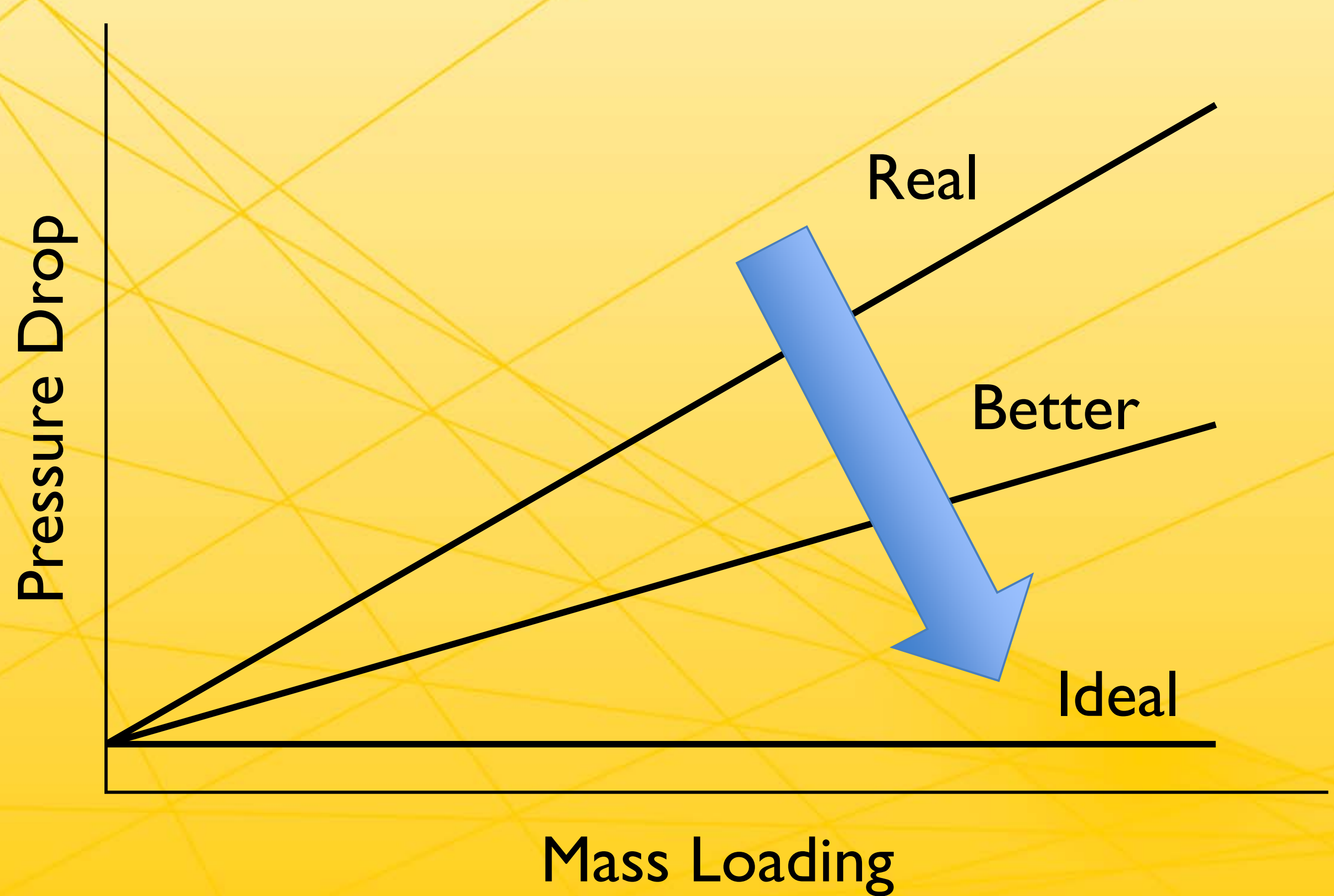
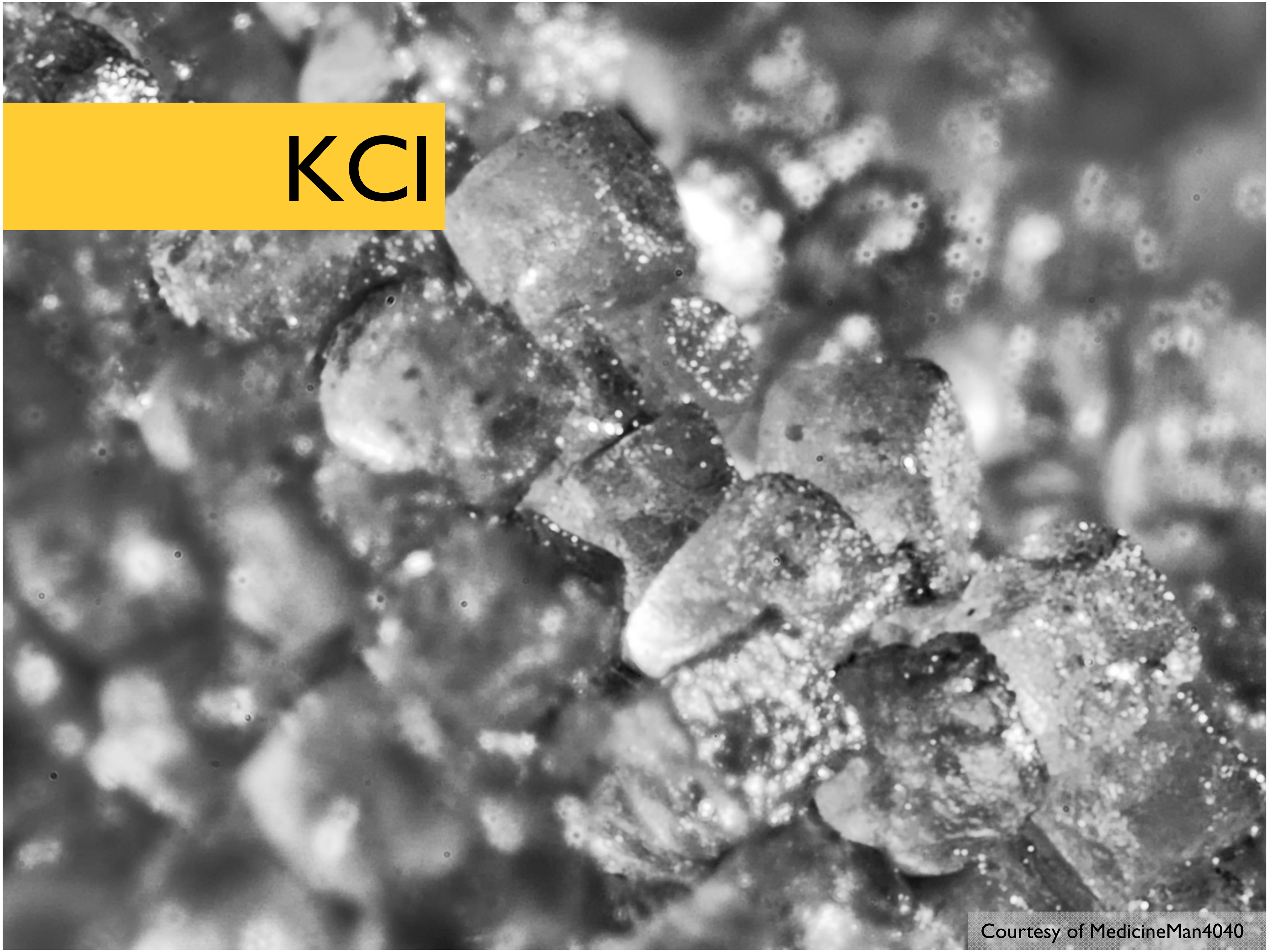

New Filter
Old Filter
Courtesy of Cyndi Wright

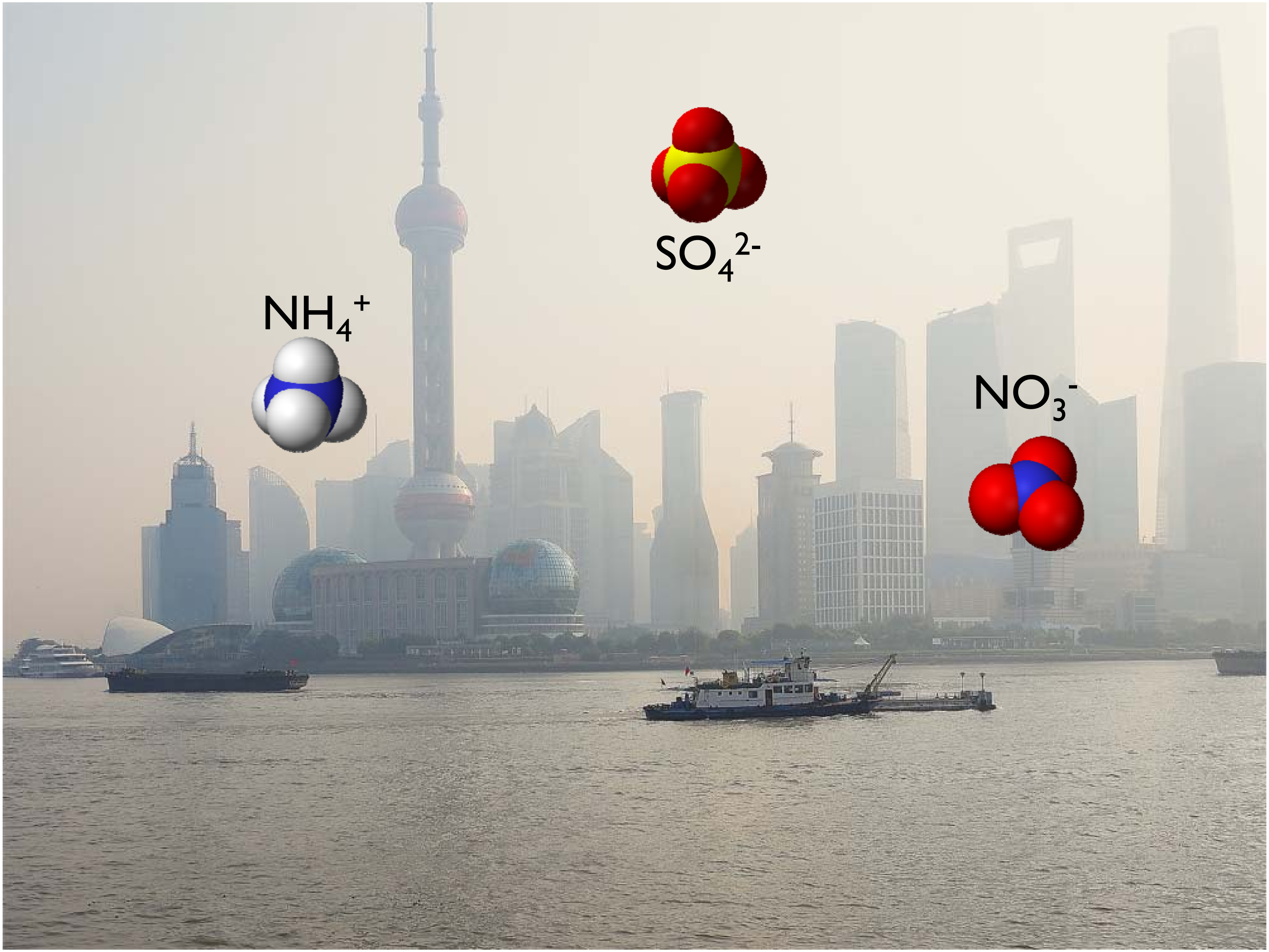

Courtesy of AAF

Filter Loading Curve

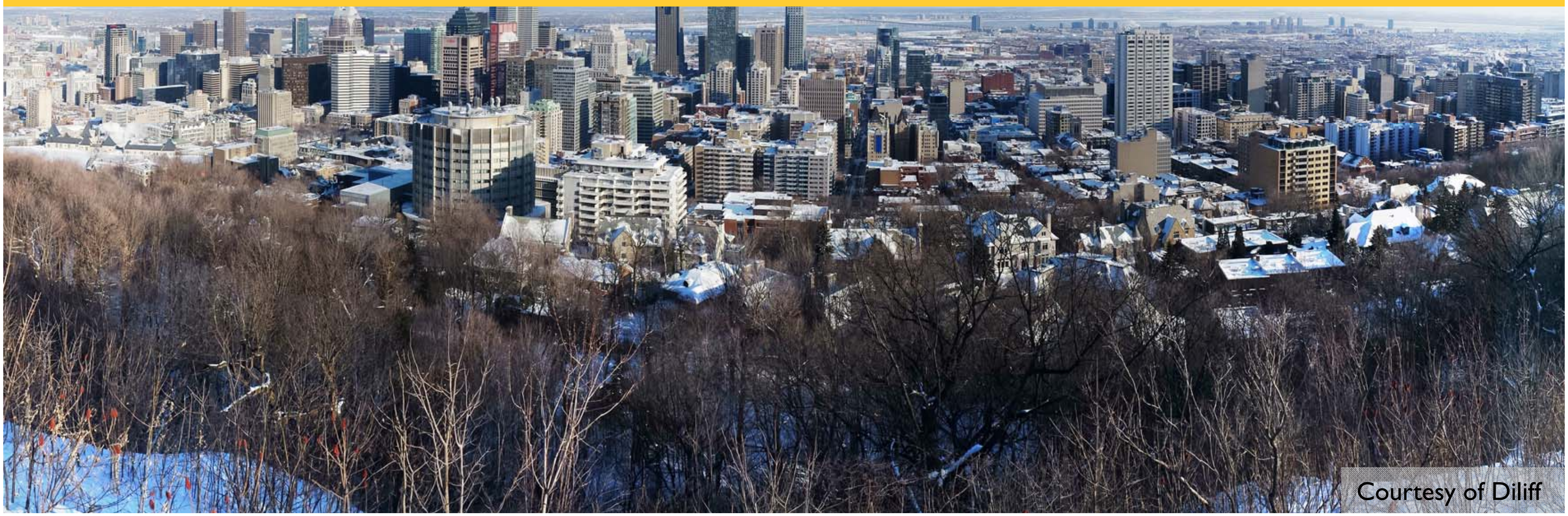



NaCl
Courtesy of Steve Begin


KCl
Courtesy of MedicineMan4040


SO_4^{2-}
NH_4^+
NO_3^-

Seasonal Variation



Courtesy of Diliff

Diurnal Variation

Courtesy of Stephen Wilkes


S.S. WOODMEN

Relevant Testing Standards

Standard	**Test Particles**	**Relative Humidity**
ASHRAE 52.2:2007	KCl / Synthetic Loading Dust	20% - 65%
ISO 5011:2014	ISO A2 & A4 dust	40% - 70%
EN 779:2012	Synthetic Loading Dust	<75%

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Previous Research

- Gupta et al. (1993) performed NaCl loading on HEPA filter below NaCl deliquescence RH.
- Migual (2003) performed NaCl loading on Polyester fiber filter below NaCl deliquescence RH.
- Joubert et al.(2010) performed NaCl loading on HEPA filter below and above NaCl deliquescence RH.

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$(NH_4)_2SO_4$

NH_4NO_3

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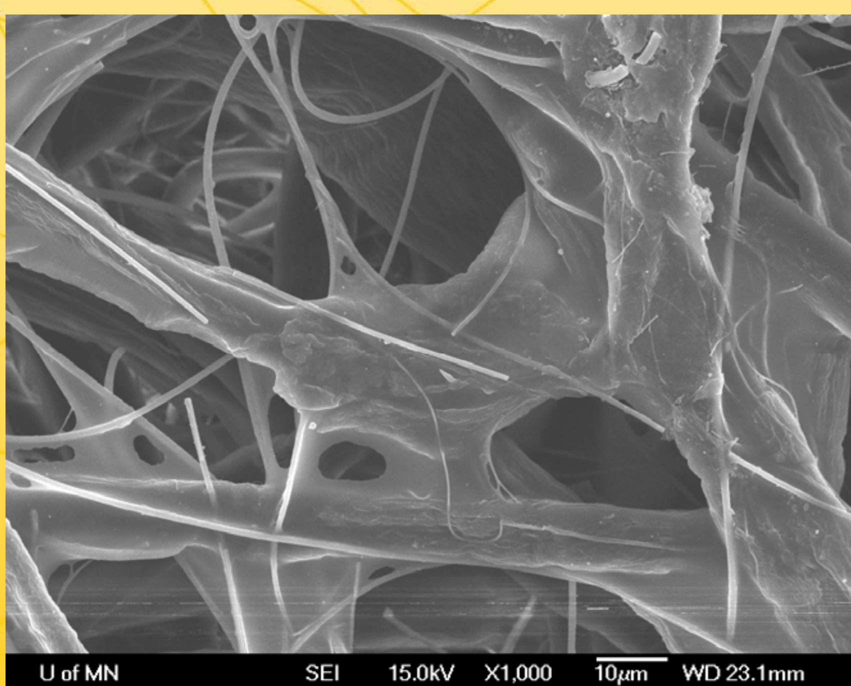
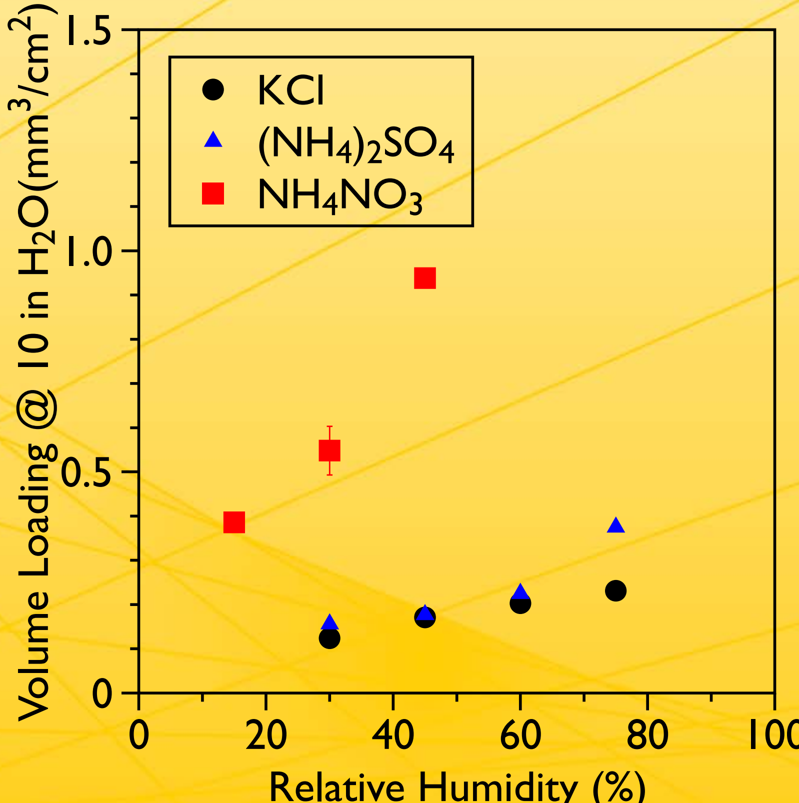
Previous Study of Conventional Cellulose Filter Media

(Last CFR Meeting)

Without Nano-fiber Coating



Volume loading results



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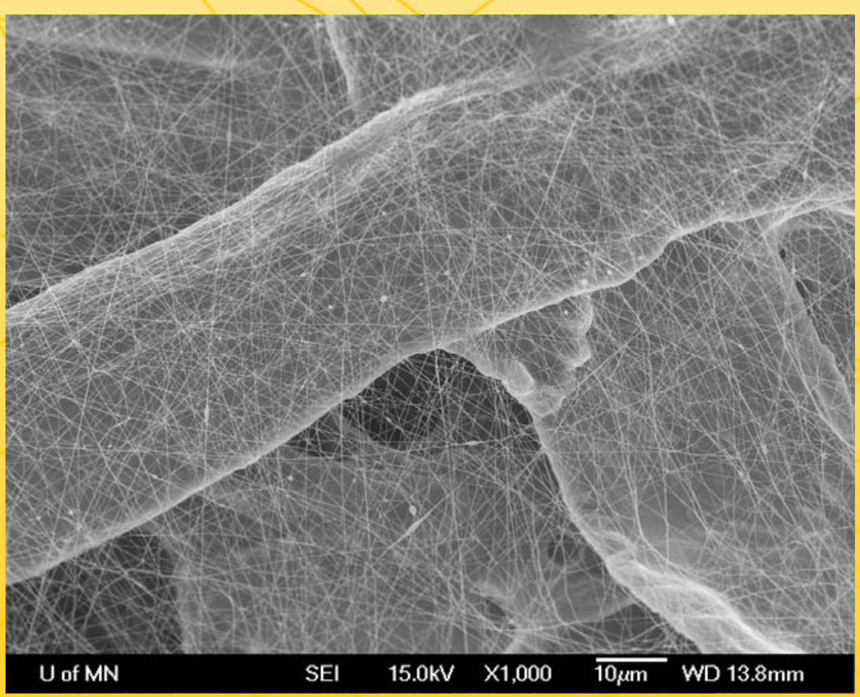
What About the Nano-fiber Coated Cellulose Filter?

With Nano-fiber Coating



- High initial efficiency
- Low pressure drop
- Resistance to clogging
- Longer life

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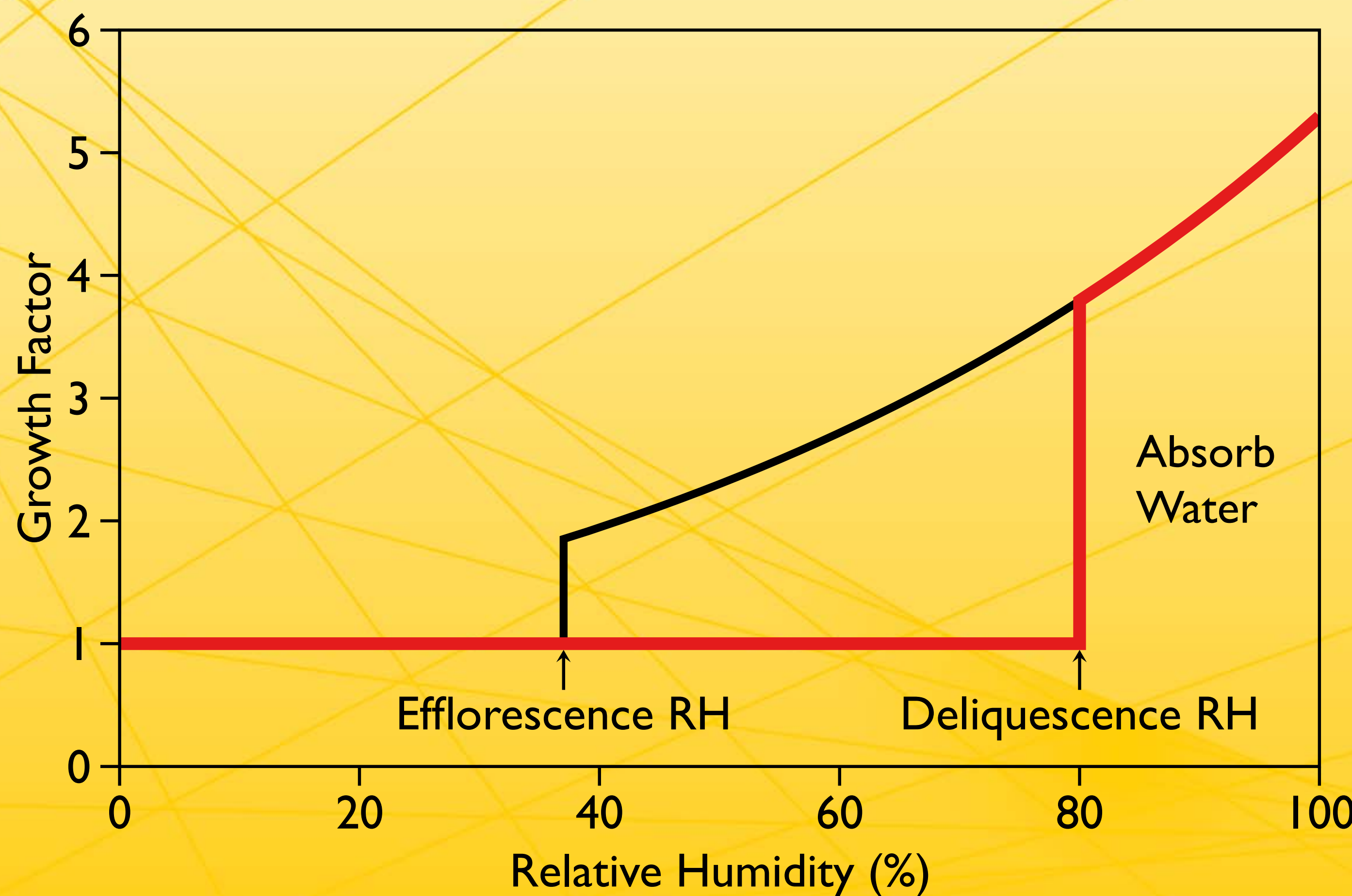
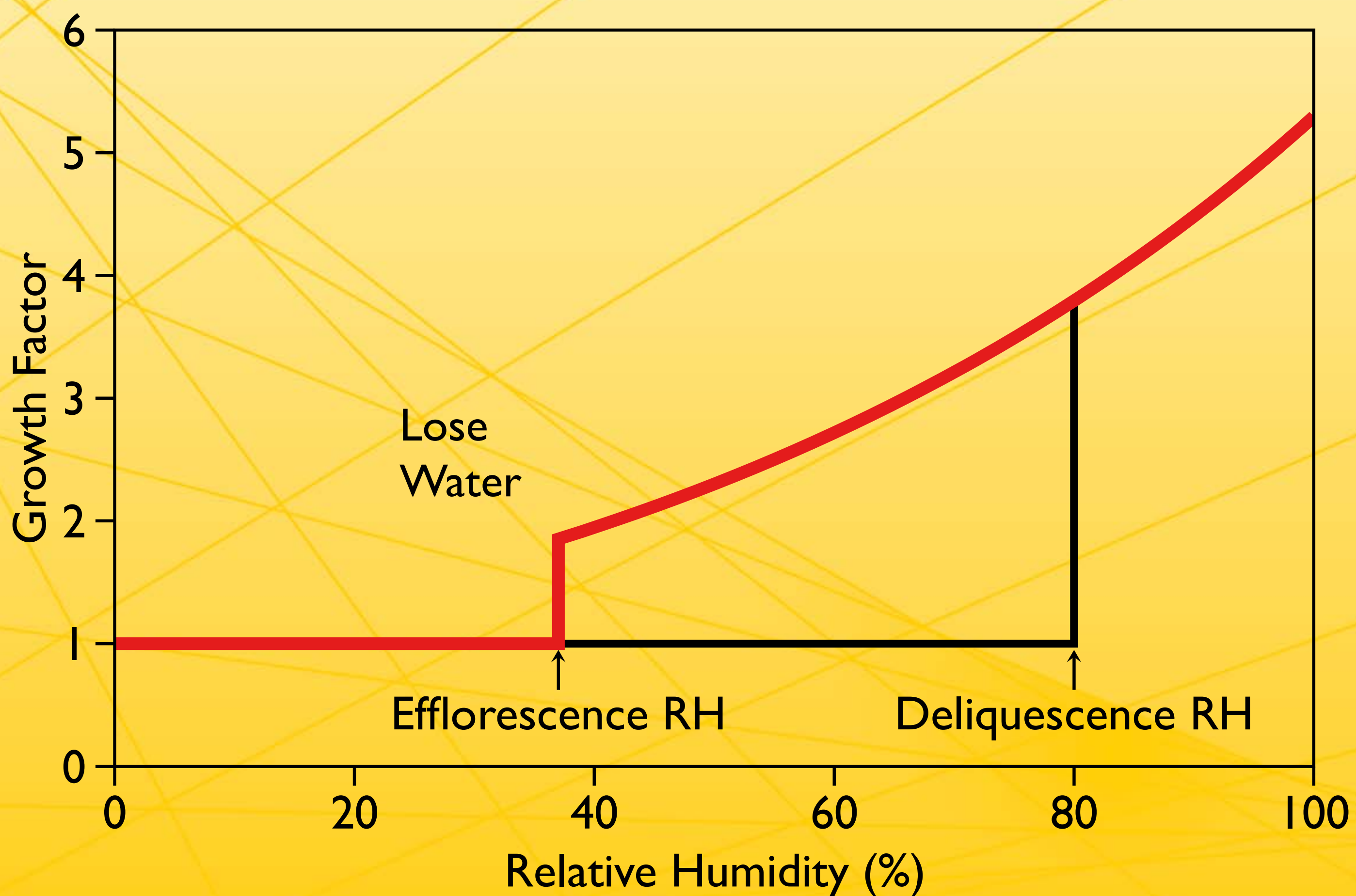
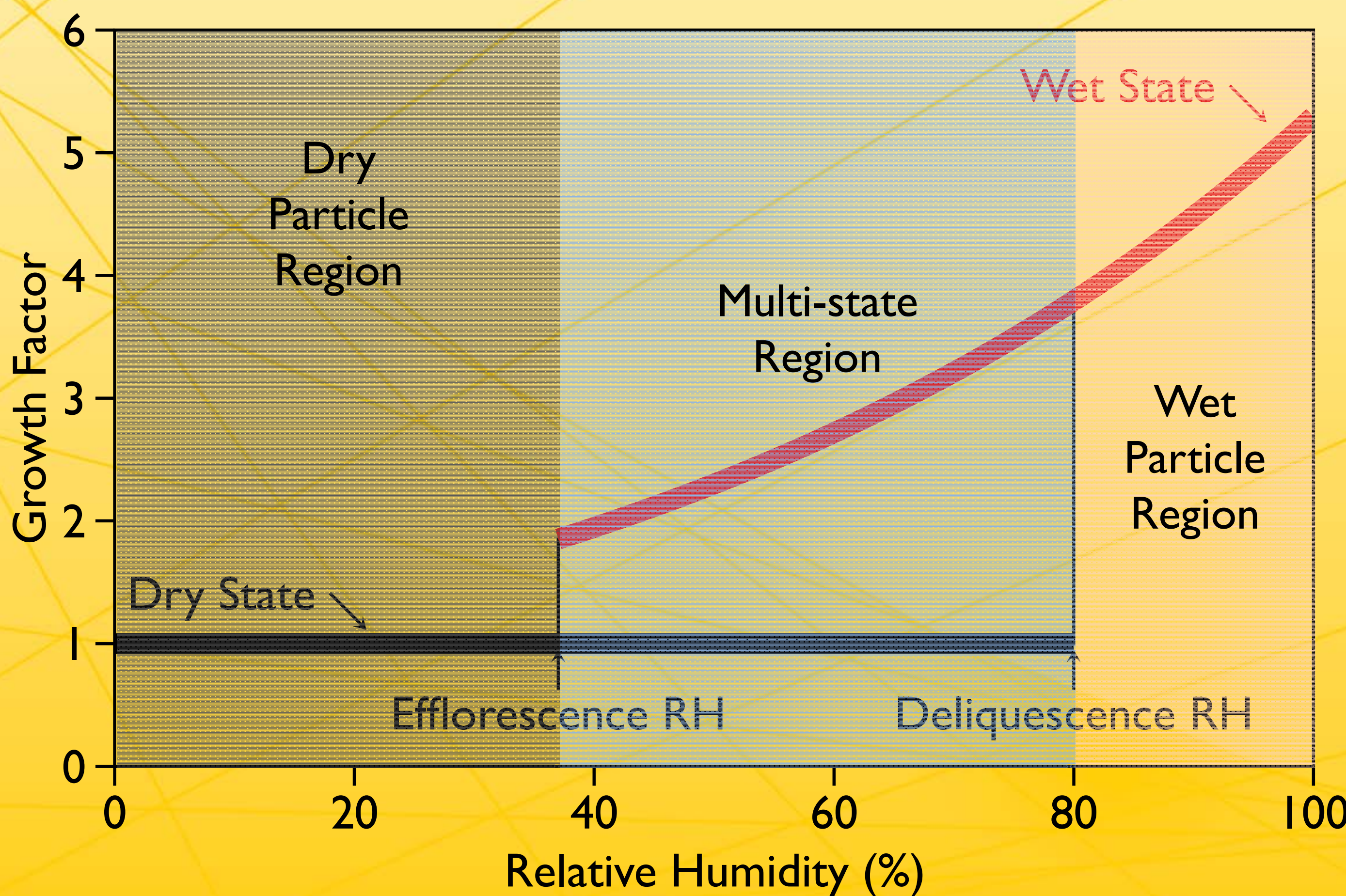
Hydration of a Salt Particle



Dehydration of a Salt Particle



Test Matrix



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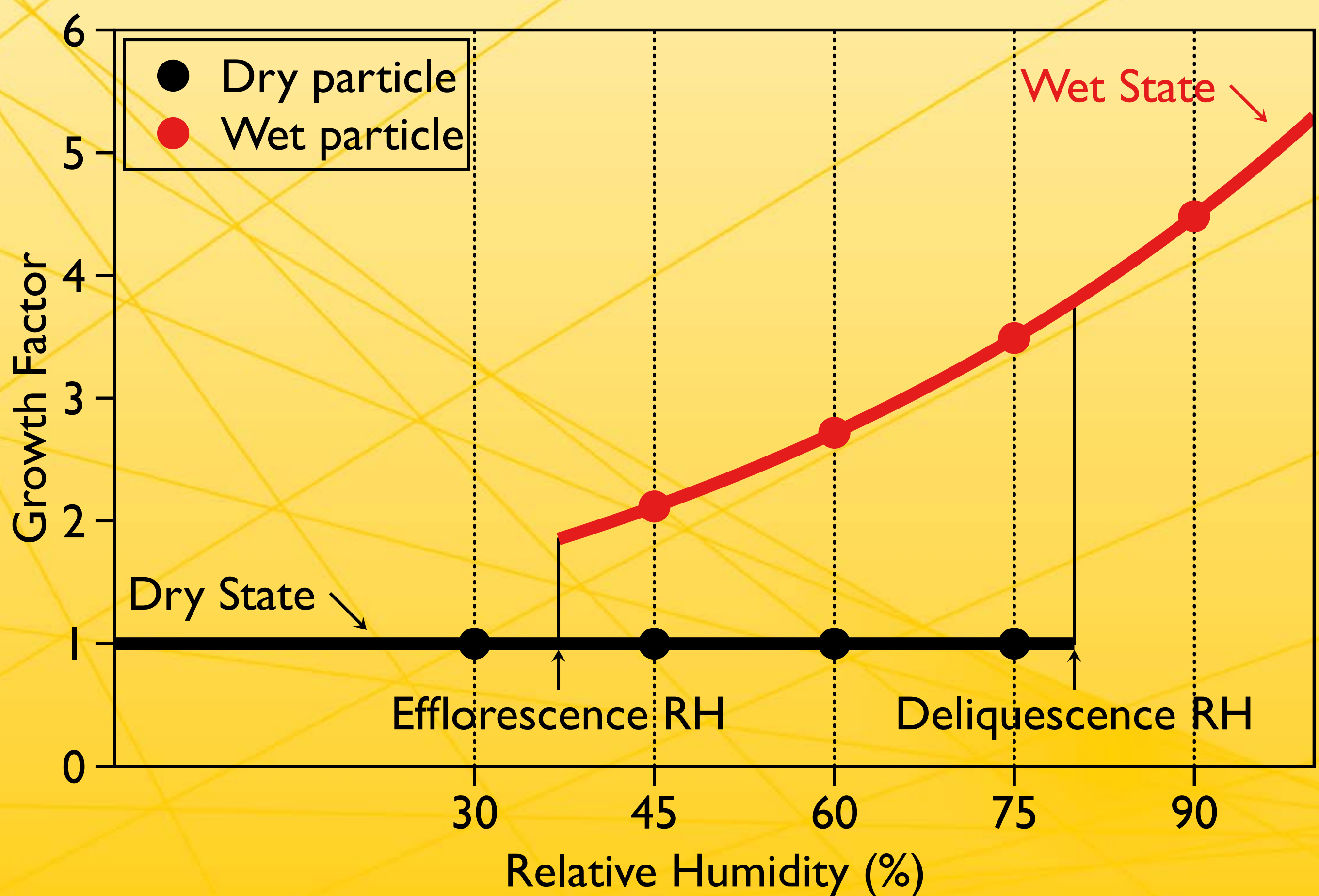
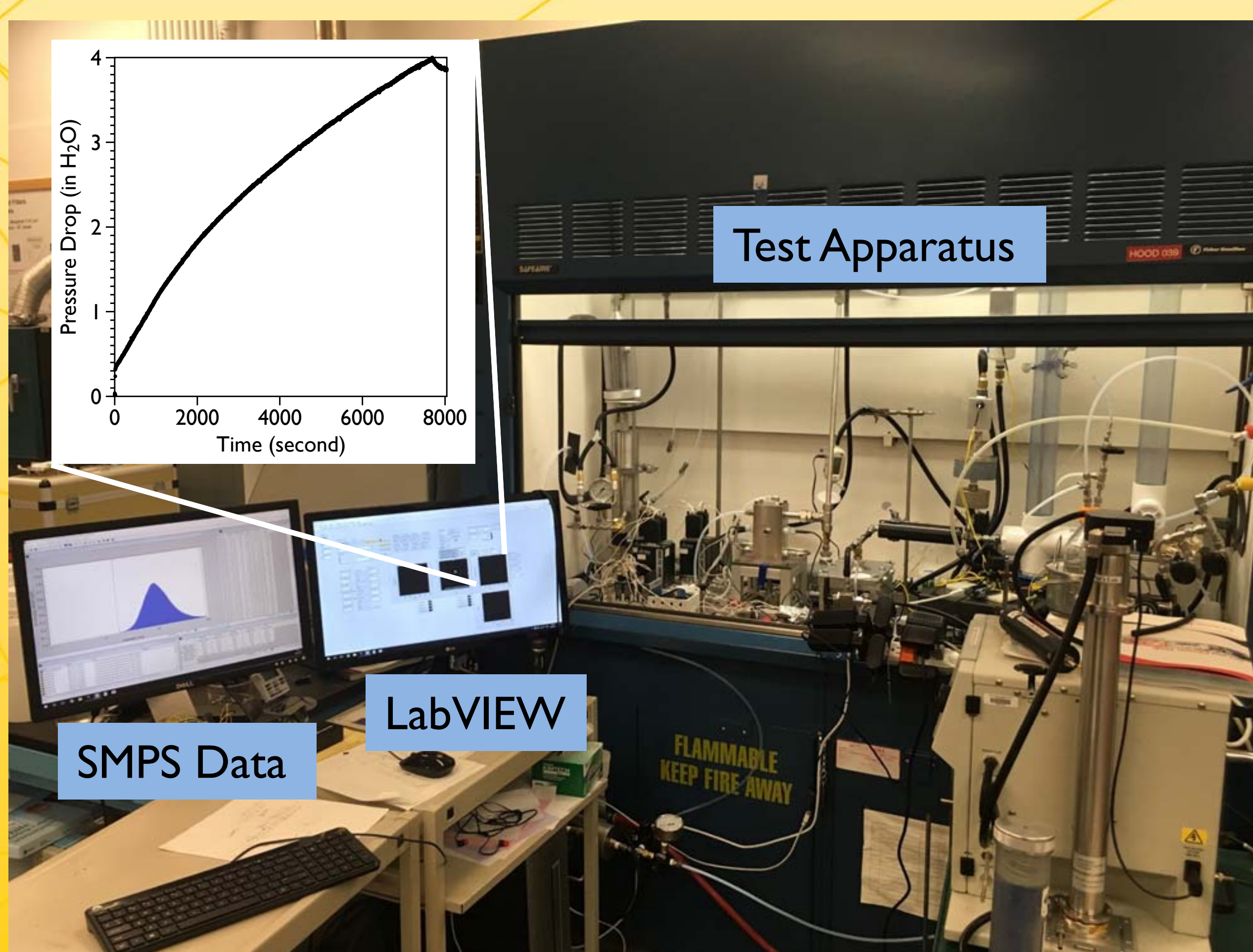
Test Matrix



Dry particle
Wet particle
Wet State
Dry State
Efflorescence RH
Deliquescence RH
Growth Factor
Relative Humidity (%)
0
1
2
3
4
5
6
30
45
60
75
90

Loading Test System



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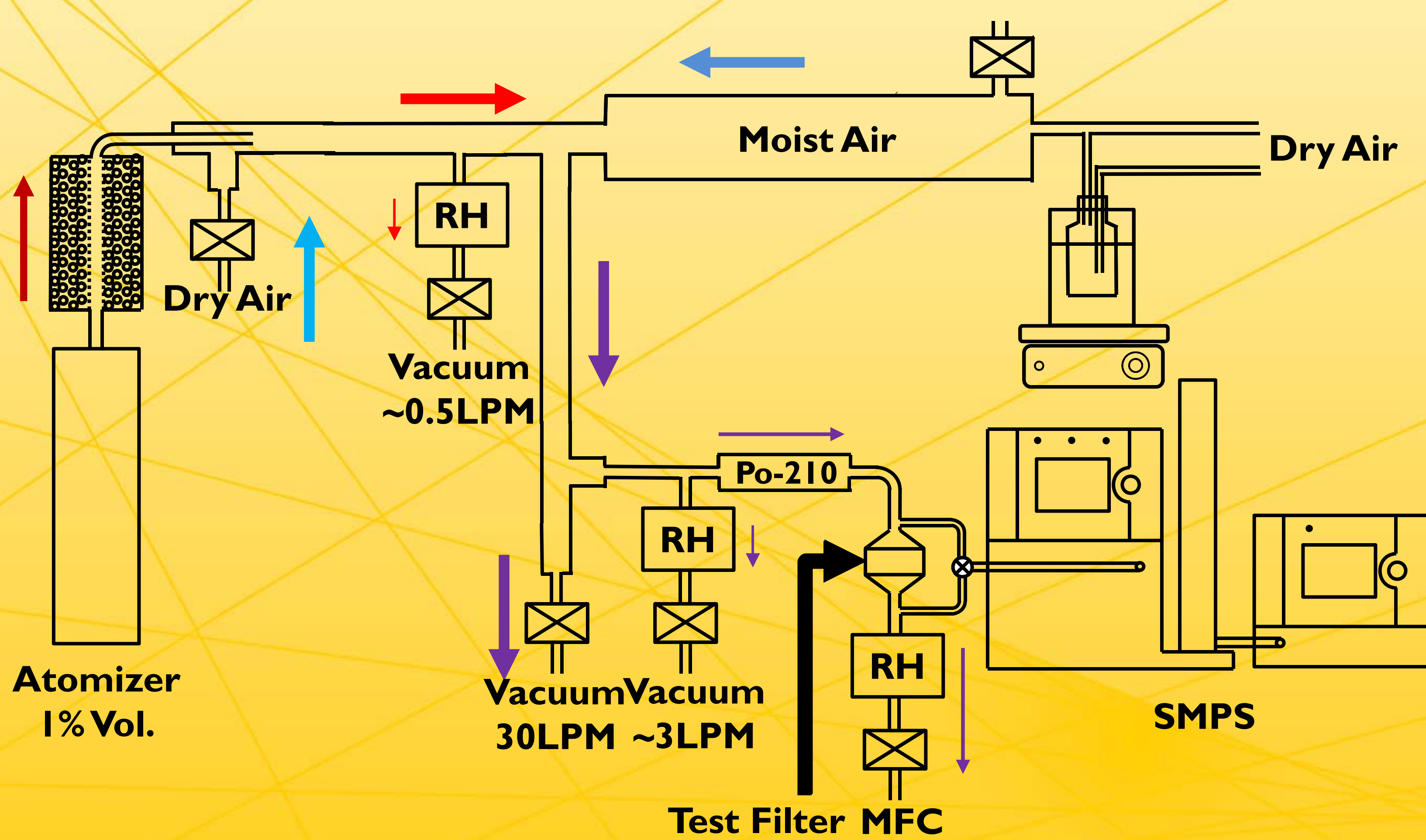
Loading Test System



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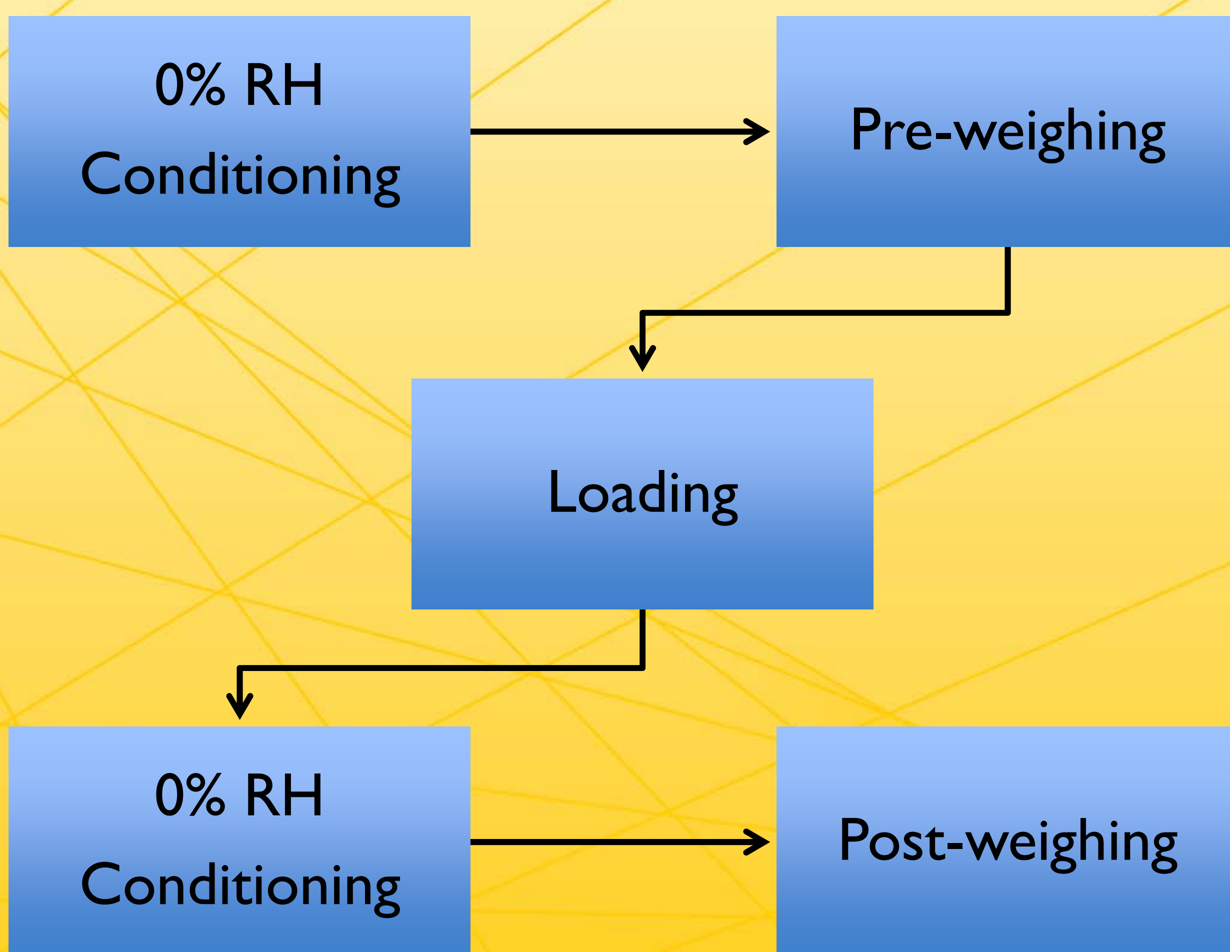
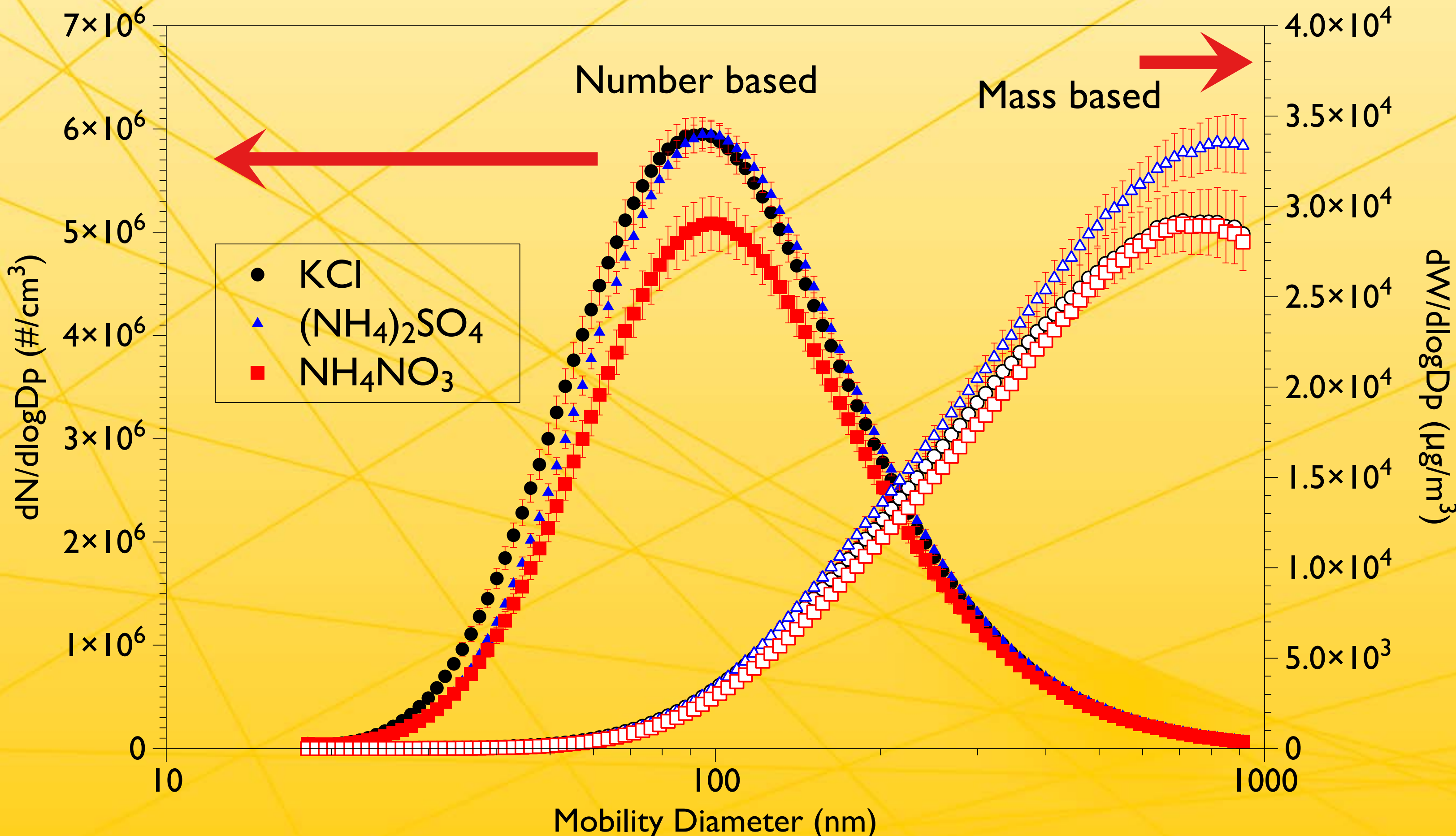
Filter Handling



Size Distribution of KCl, $(NH_4)_2SO_4$, and NH_4NO_3



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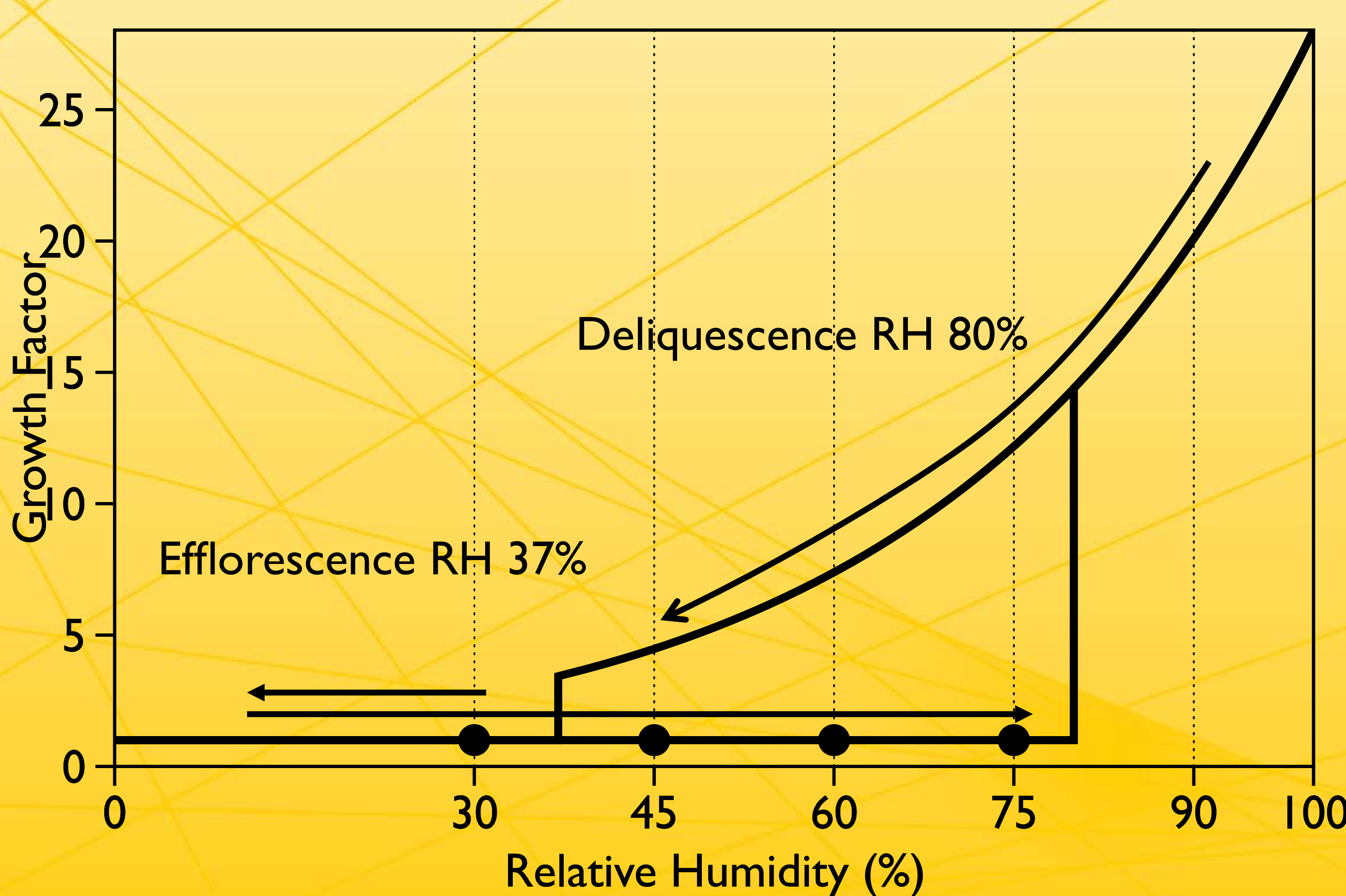
KCl

$(NH_4)_2SO_4$

Dehydration of $(NH_4)_2SO_4$
Dry $(NH_4)_2SO_4$



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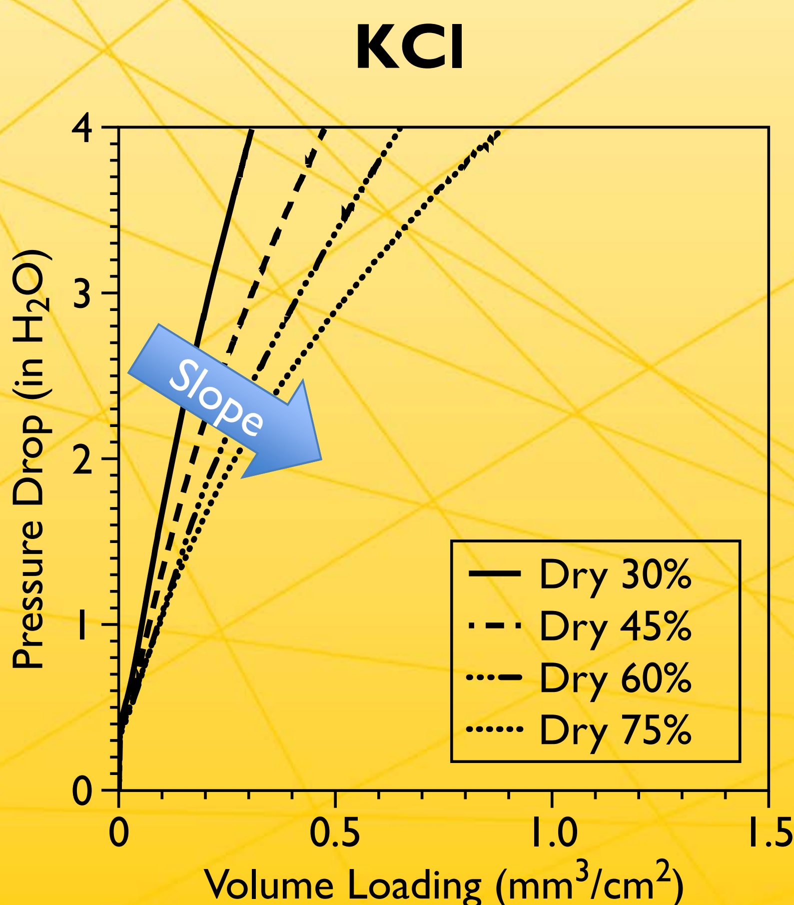
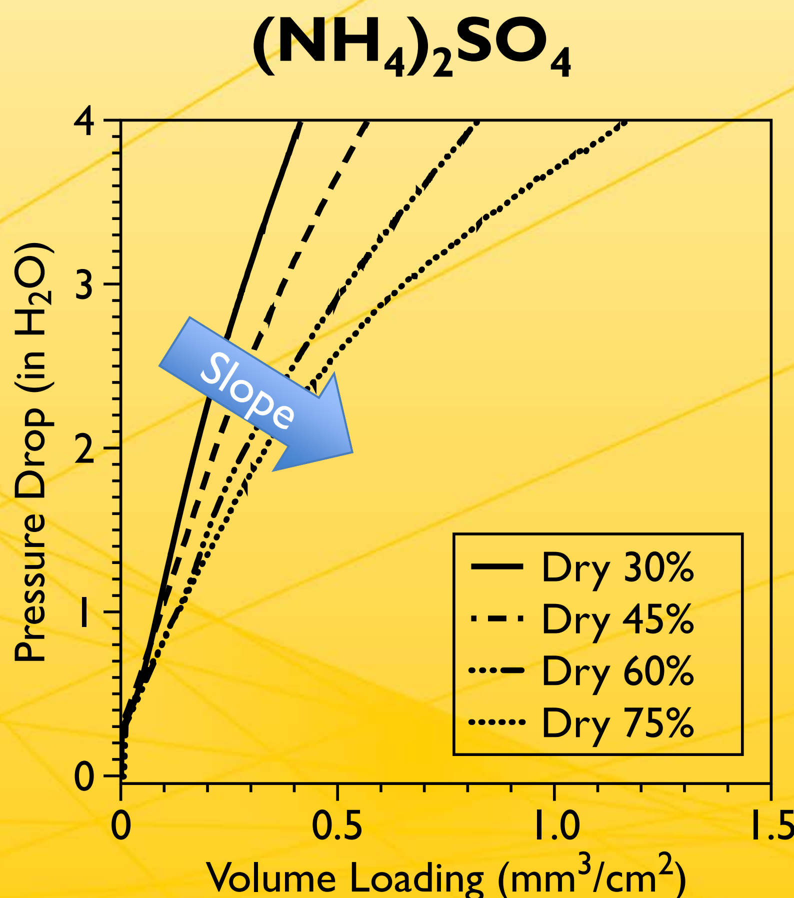
Dry KCl & $(NH_4)_2SO_4$ Loading Curves





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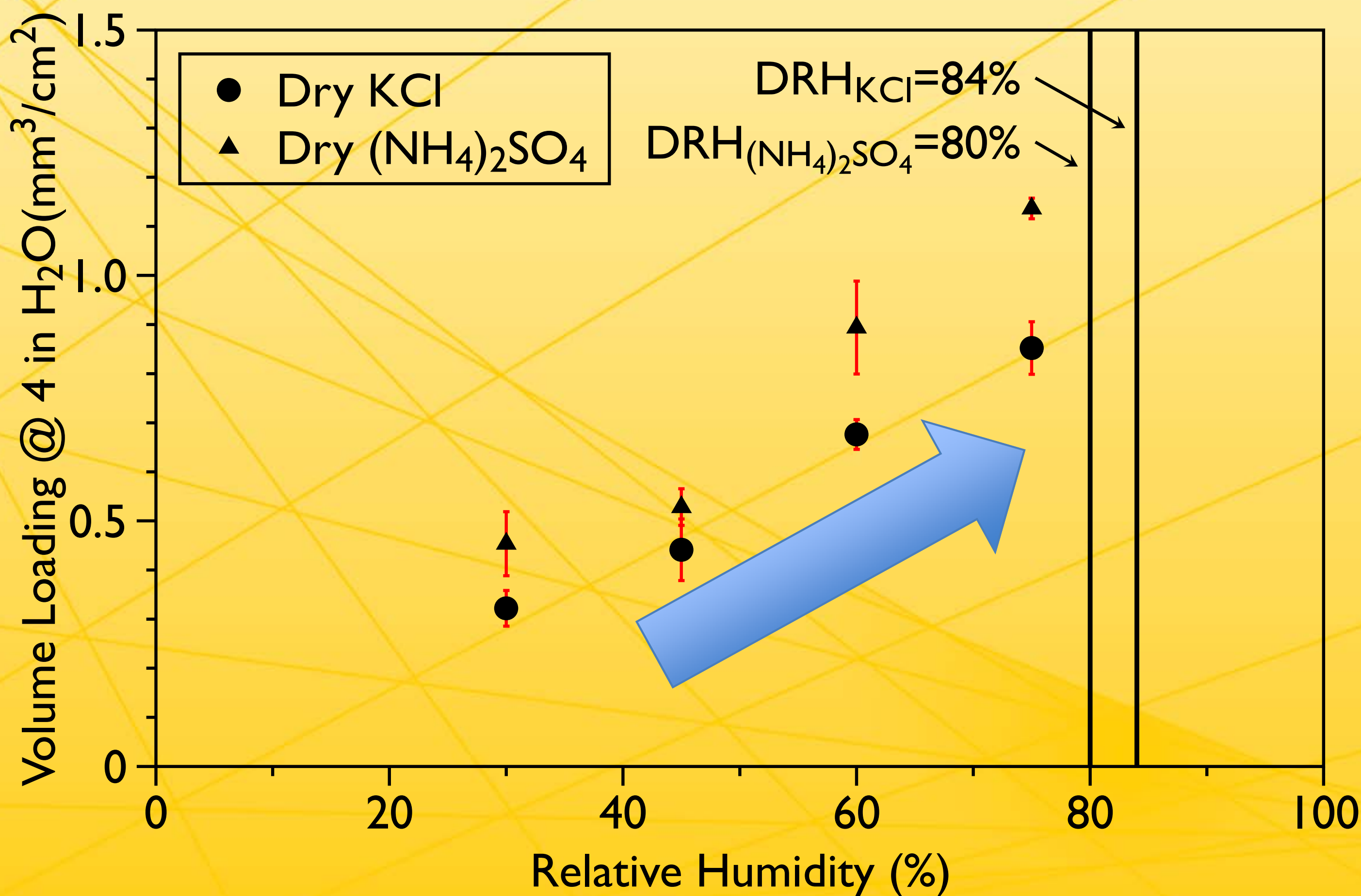
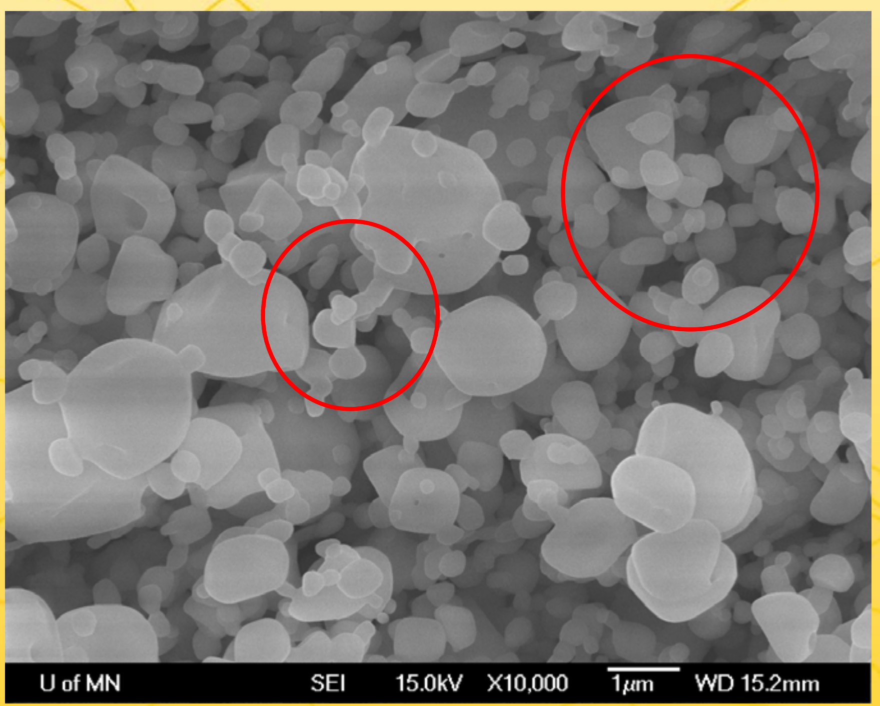
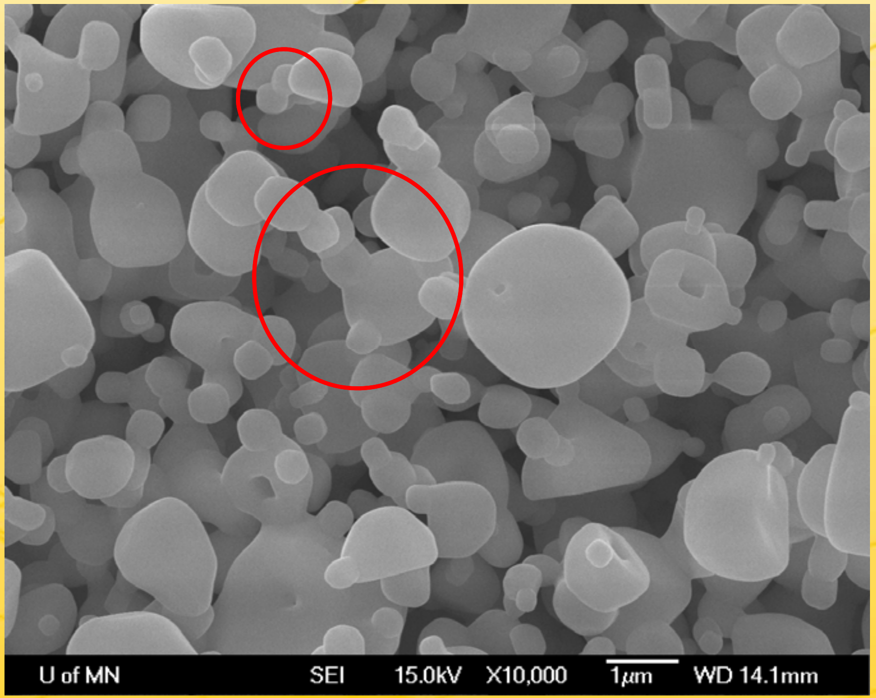
Dry KCl and $(NH_4)_2SO_4$ Volume Loading @ Different RHs



Dry@30%RH

Dry@75%RH





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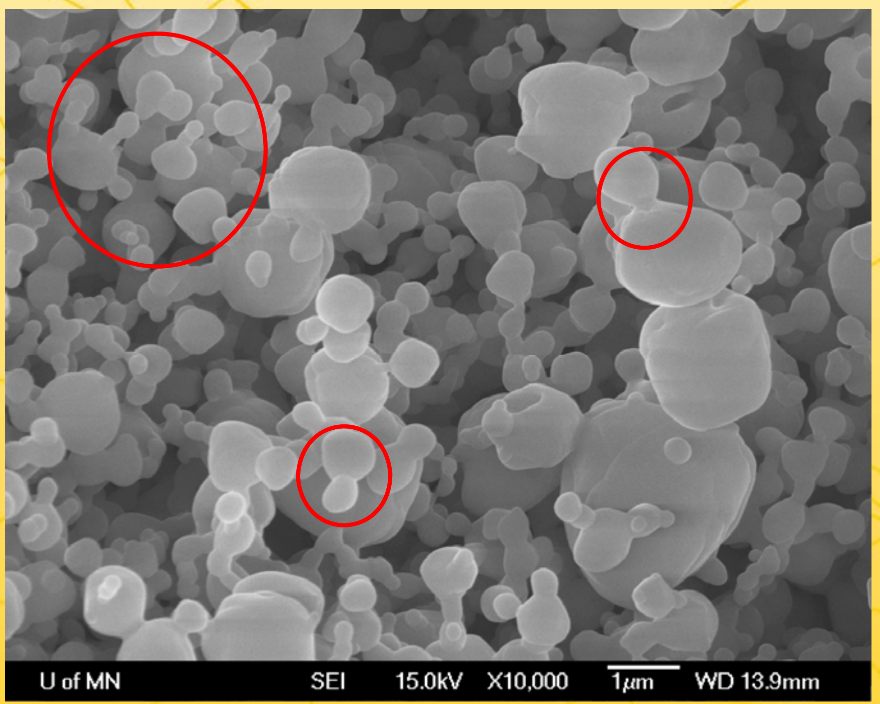
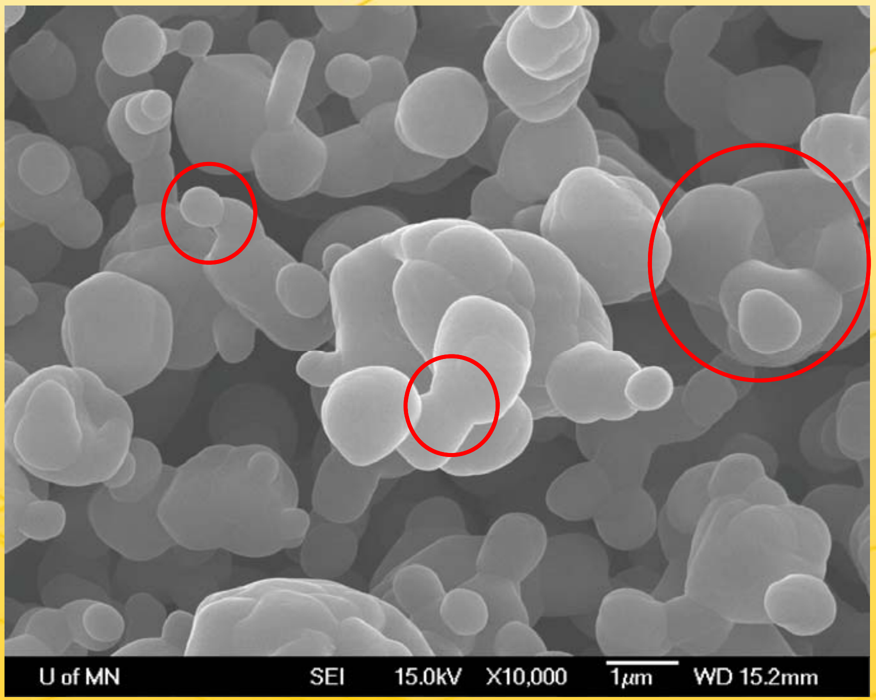
Dry@30%RH



Dry@75%RH



$(NH_4)_2SO_4$

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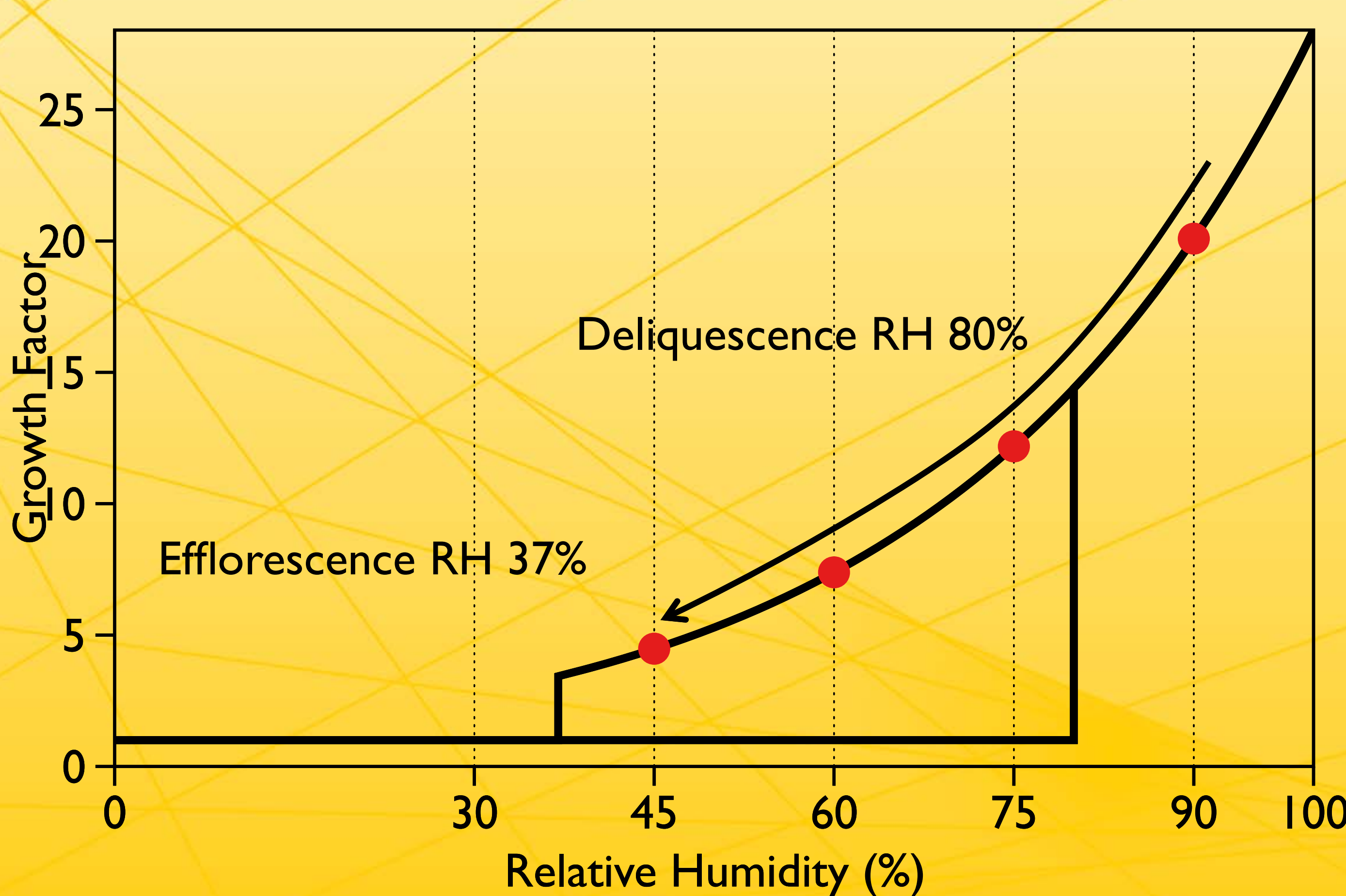
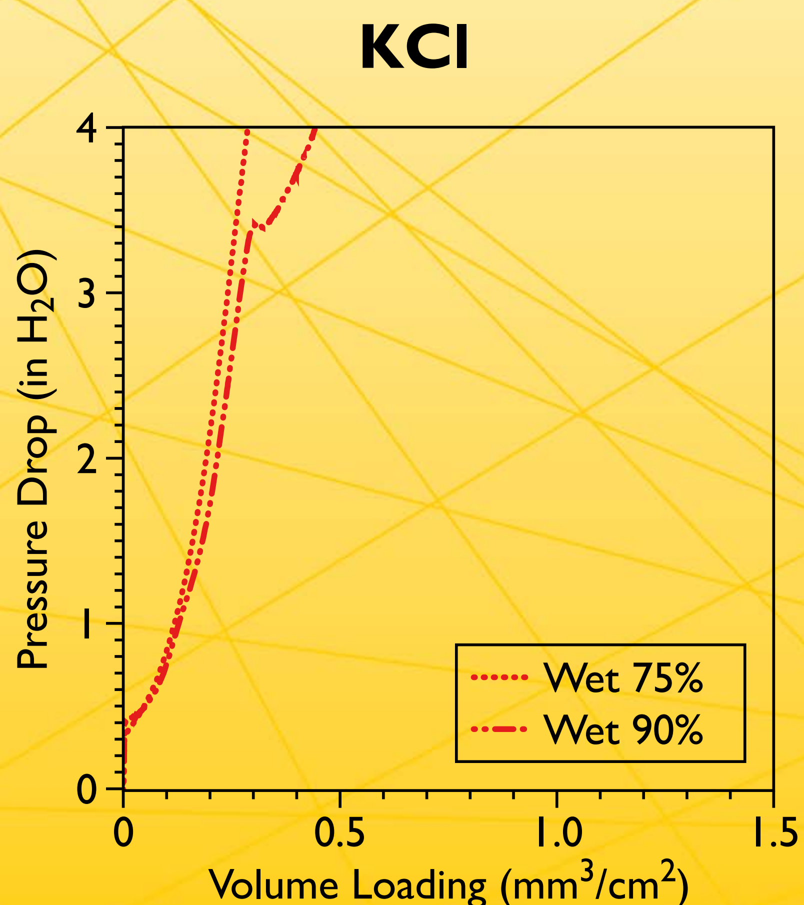
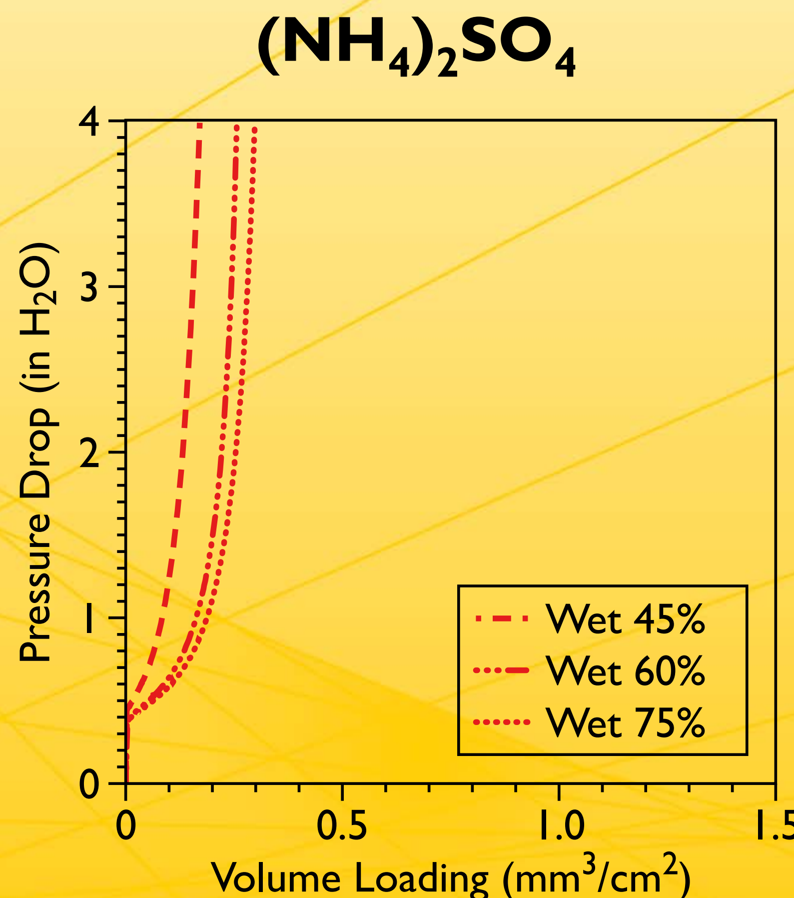
Dehydration of $(NH_4)_2SO_4$
Wet $(NH_4)_2SO_4$



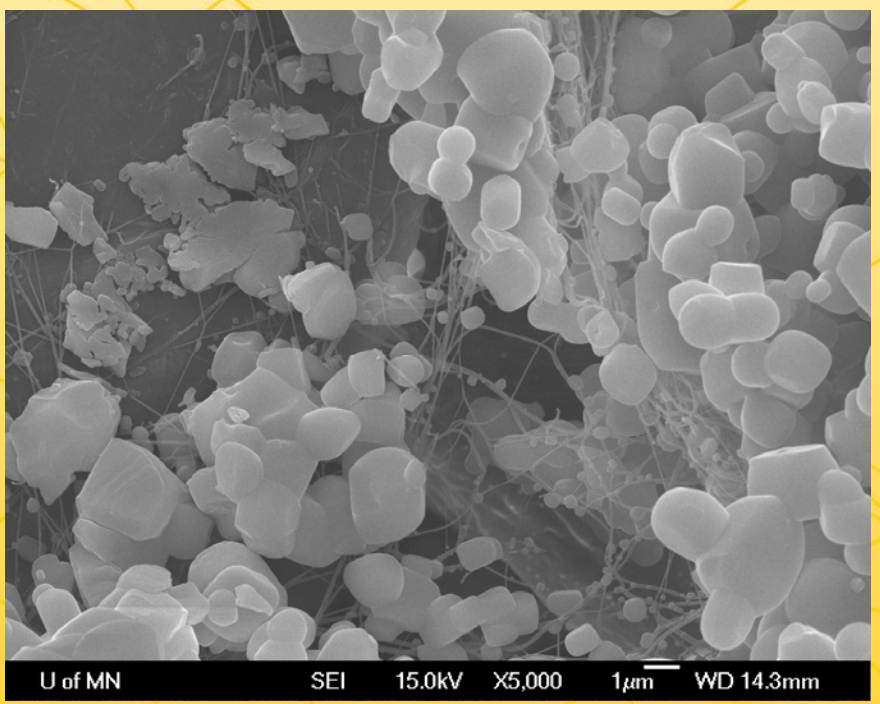
Wet KCl & $(NH_4)_2SO_4$ Loading Curves

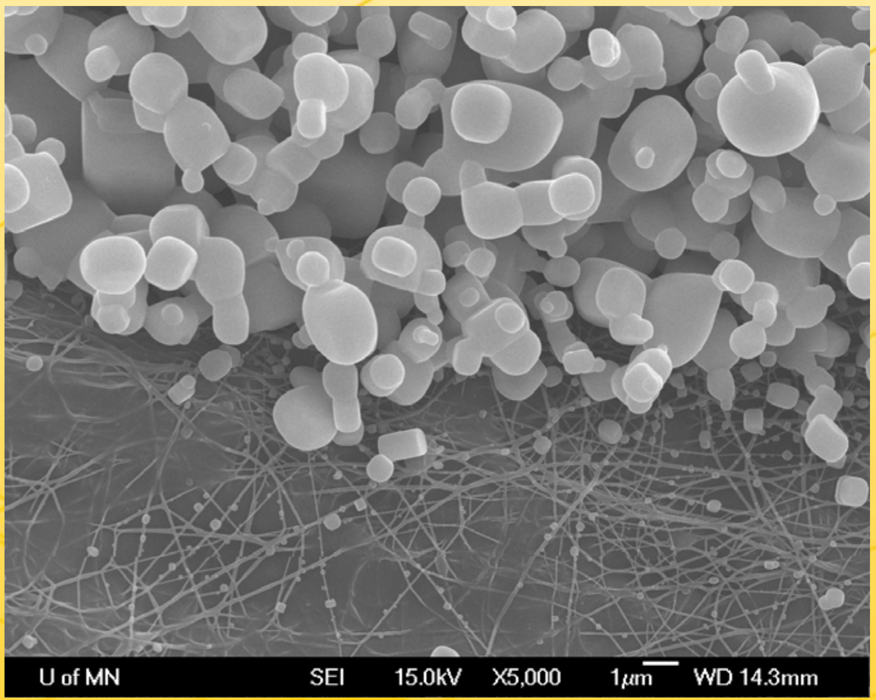




Wet@75%RH

Wet@90%RH





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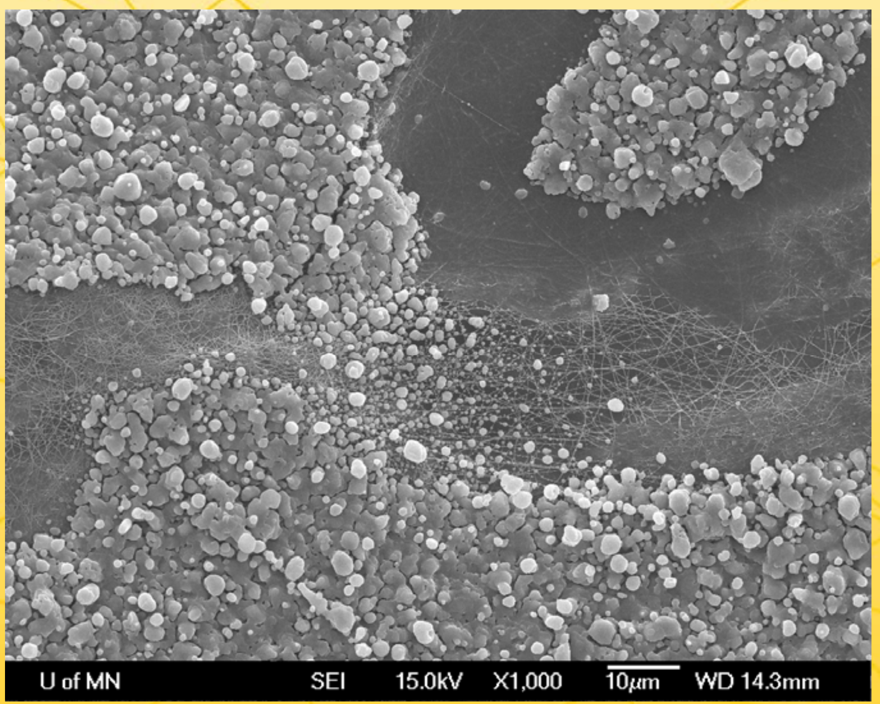
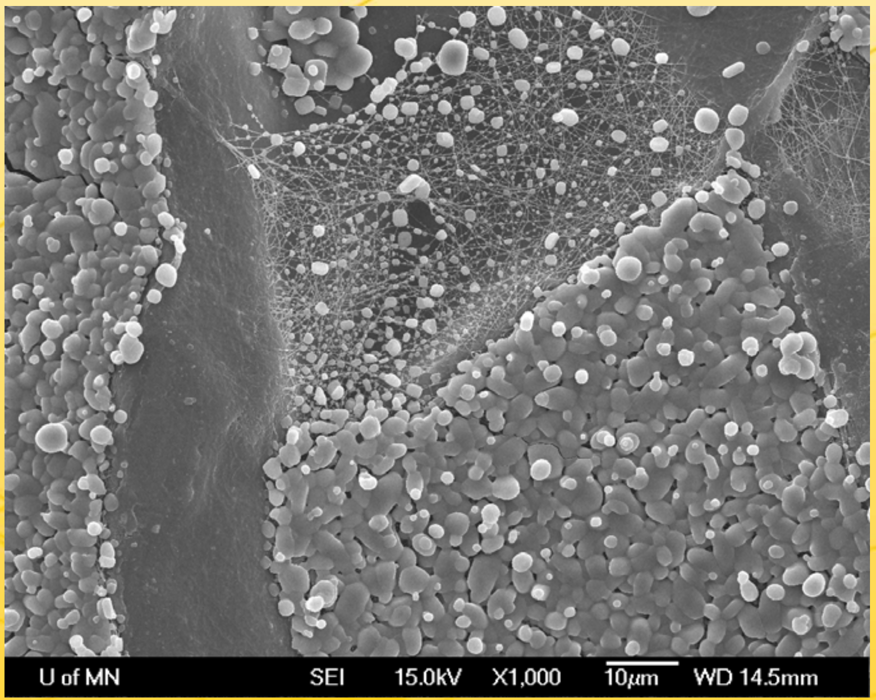
Wet@45%RH Wet@75%RH





$(NH_4)_2SO_4$

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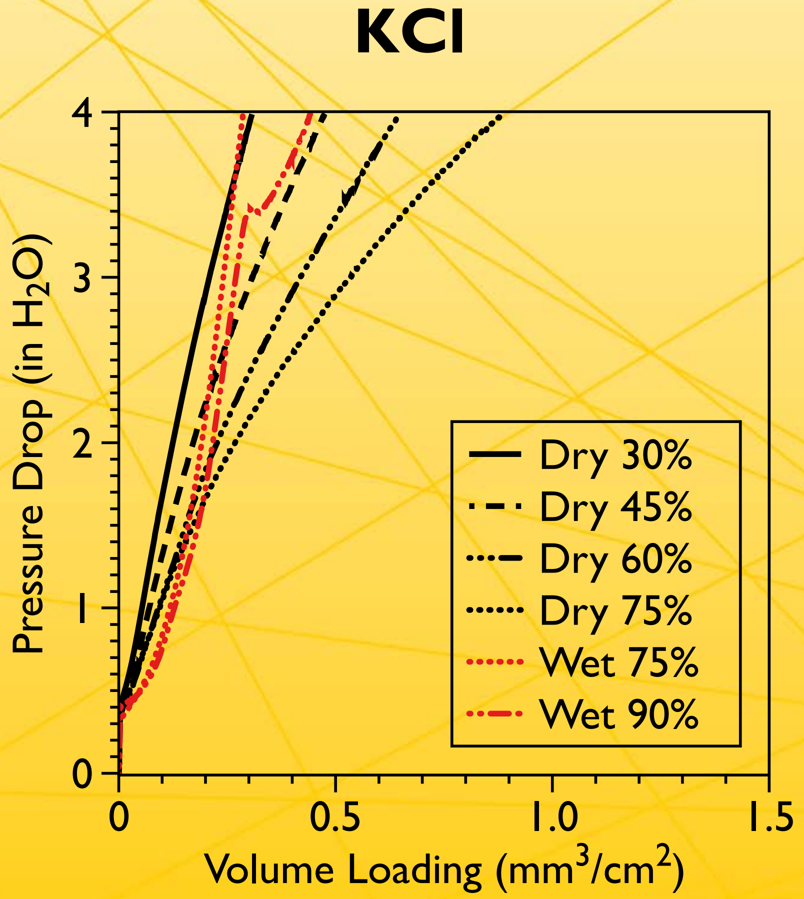
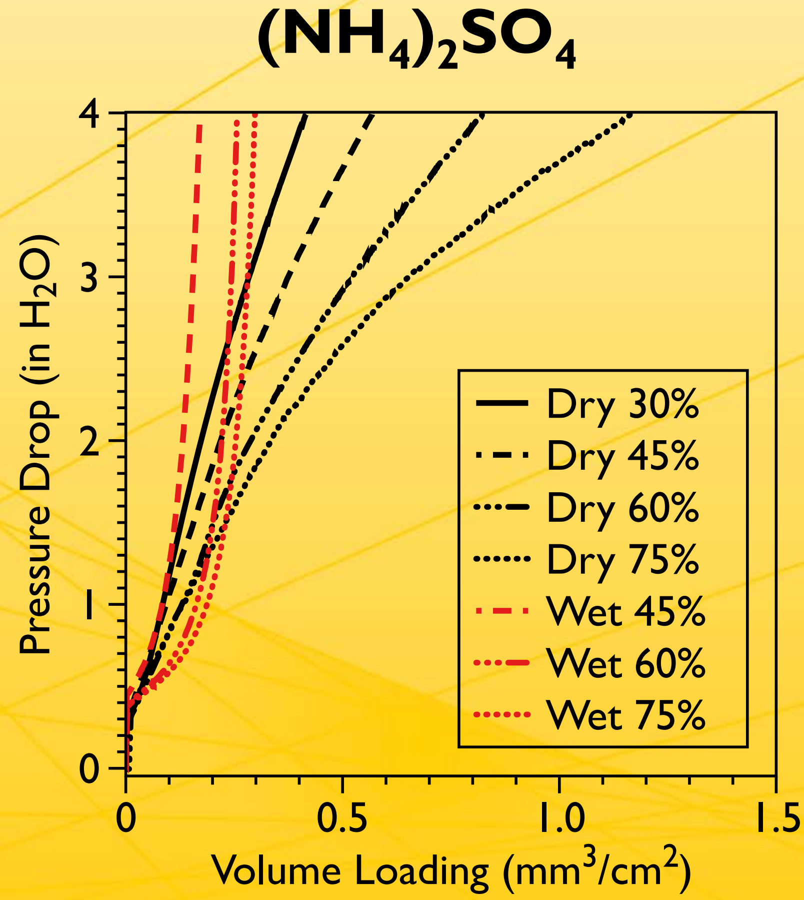
KCl & $(NH_4)_2SO_4$ Loading Curves





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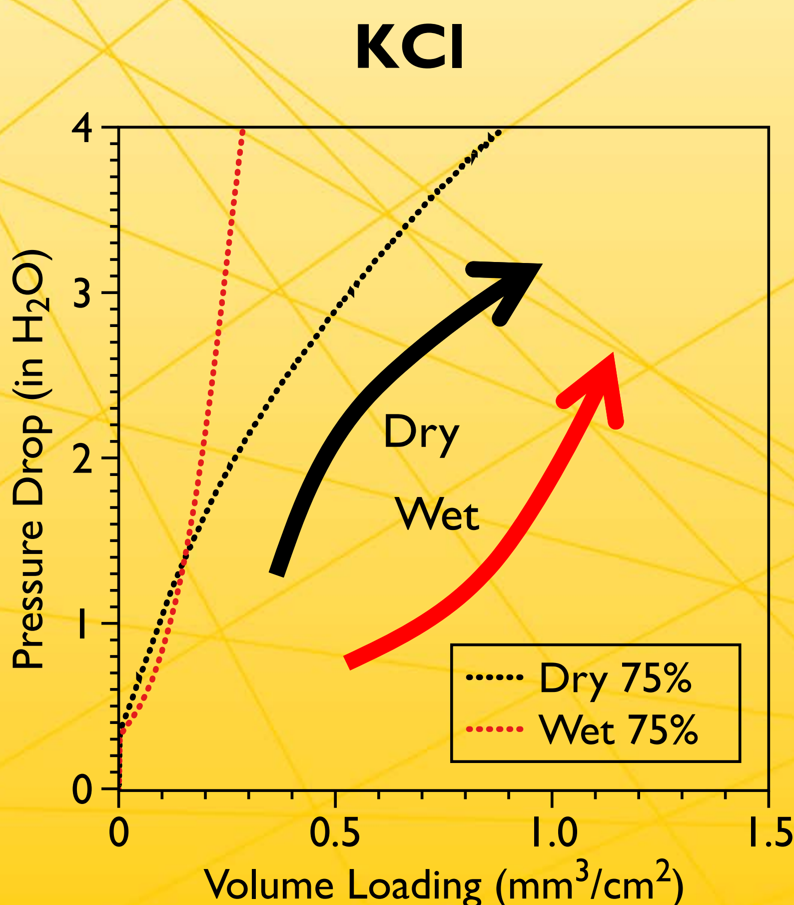
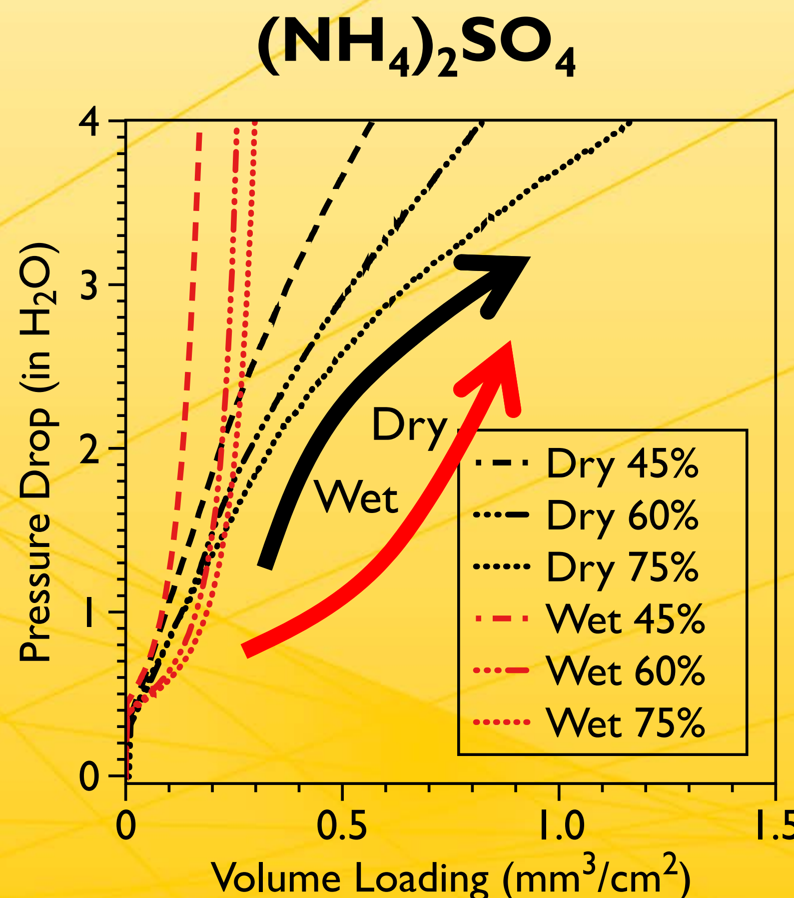
KCl & $(NH_4)_2SO_4$ Loading Curves





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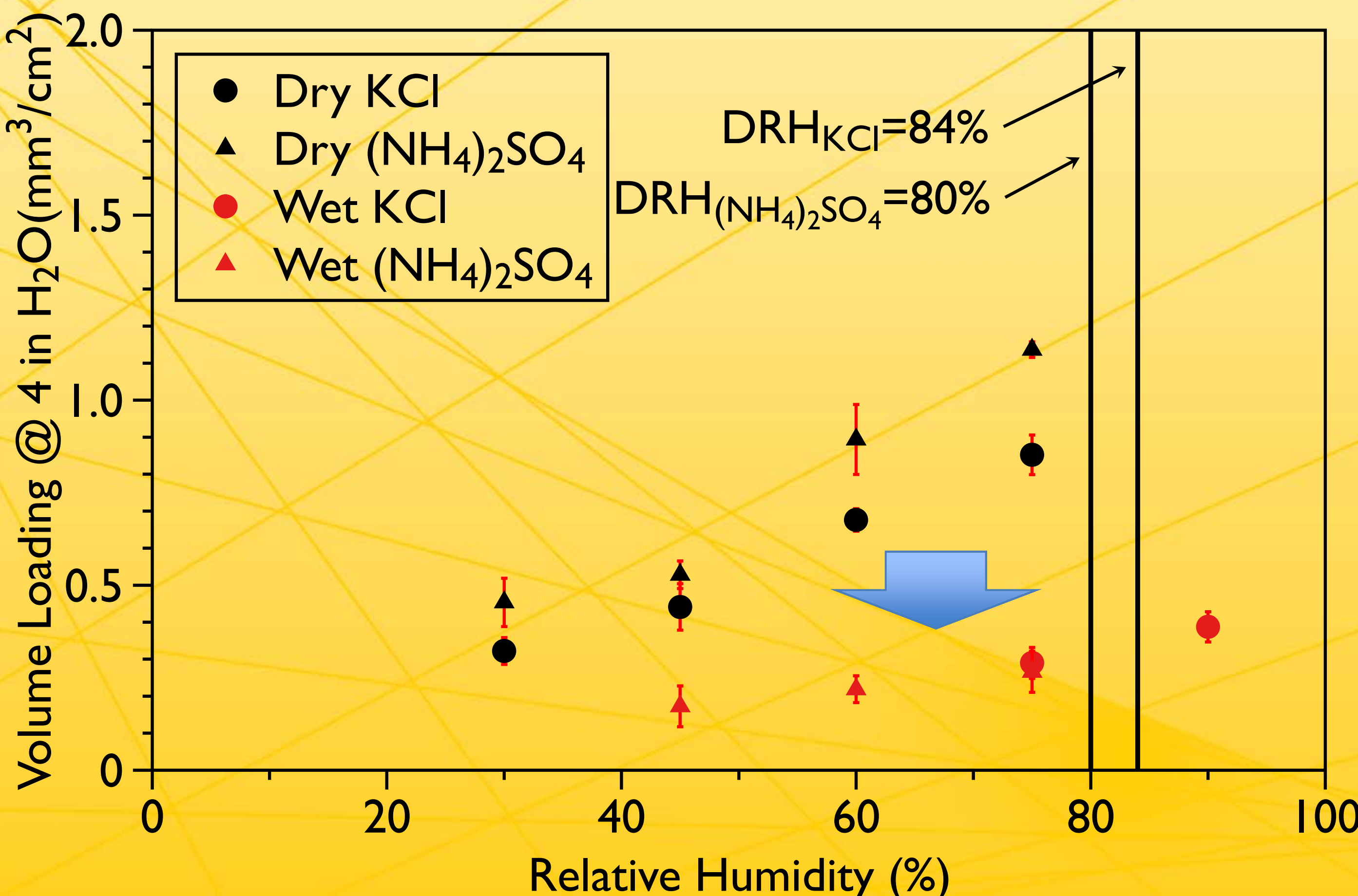
KCl and $(NH_4)_2SO_4$ Volume Loading @ Different RHs



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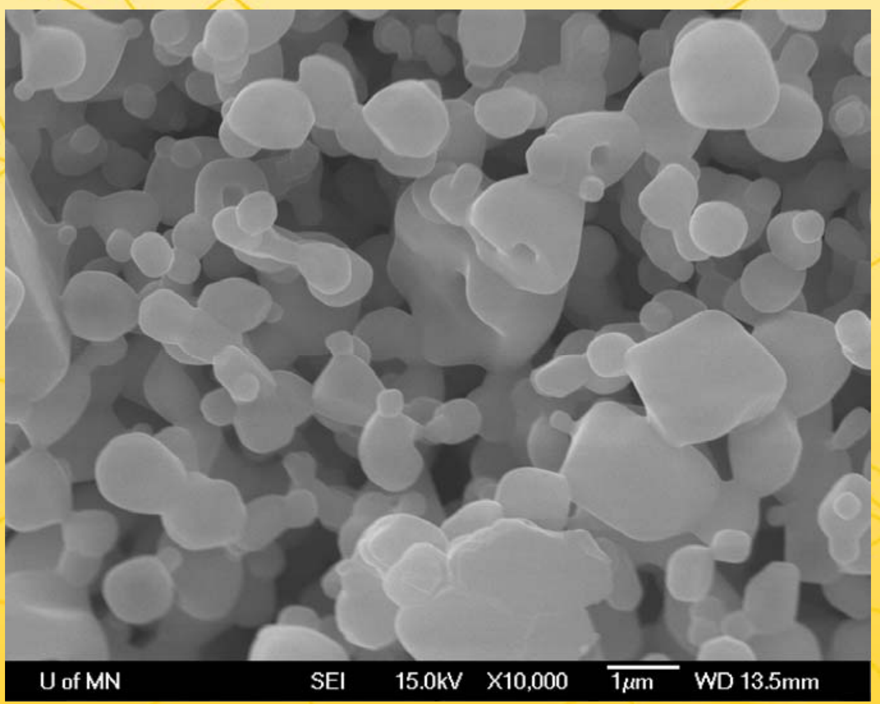
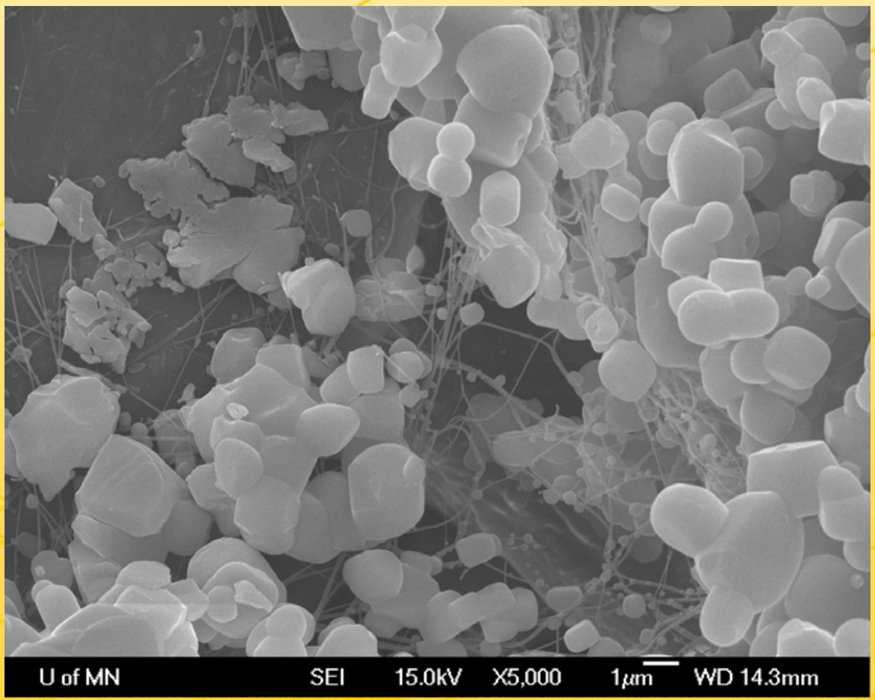
Dry@75%RH



Wet@75%RH



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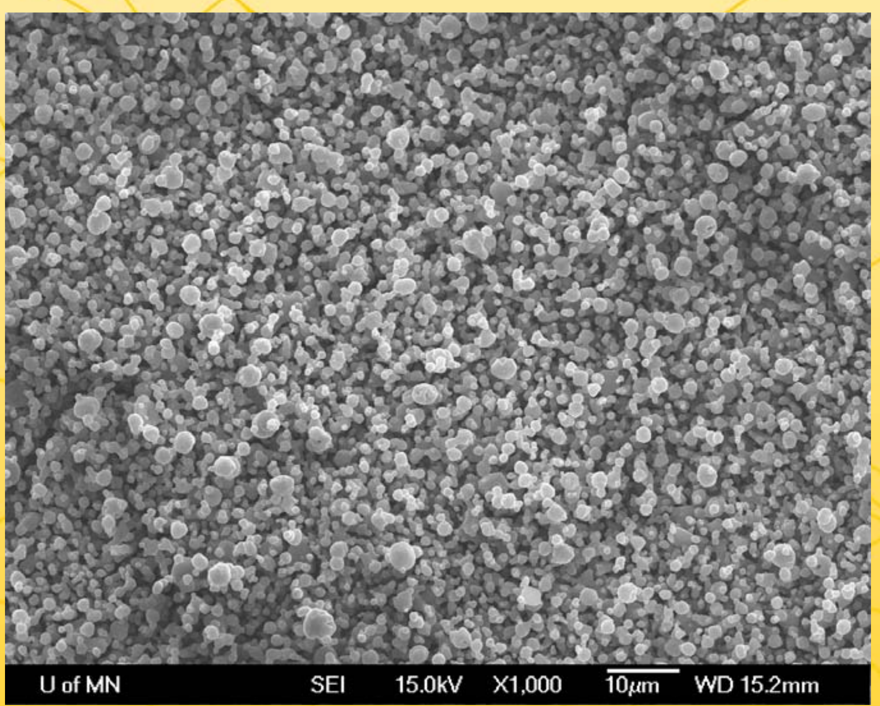
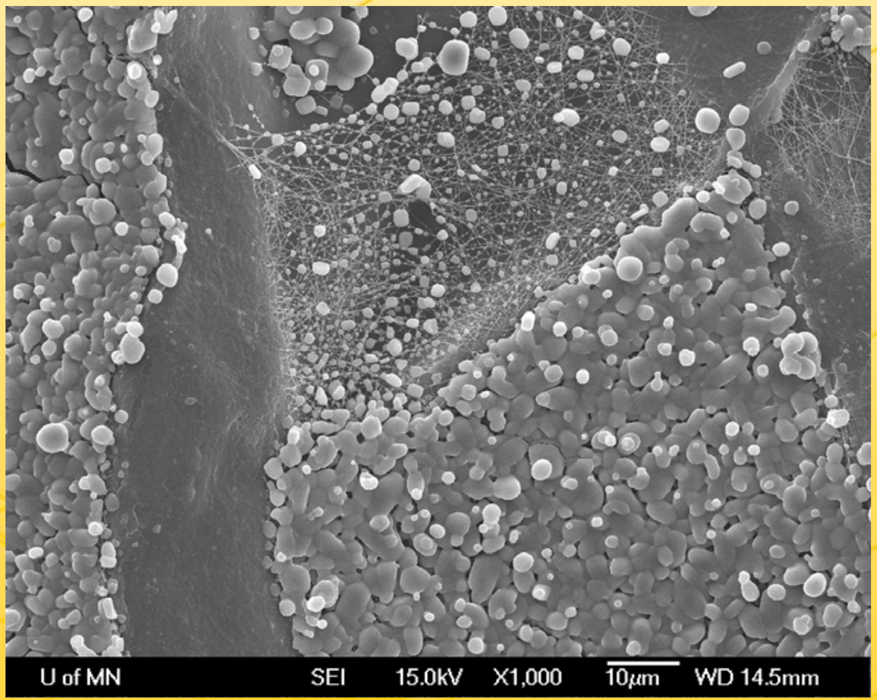
Dry@75%RH

Wet@75%RH





$(NH_4)_2SO_4$

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NH_4NO_3

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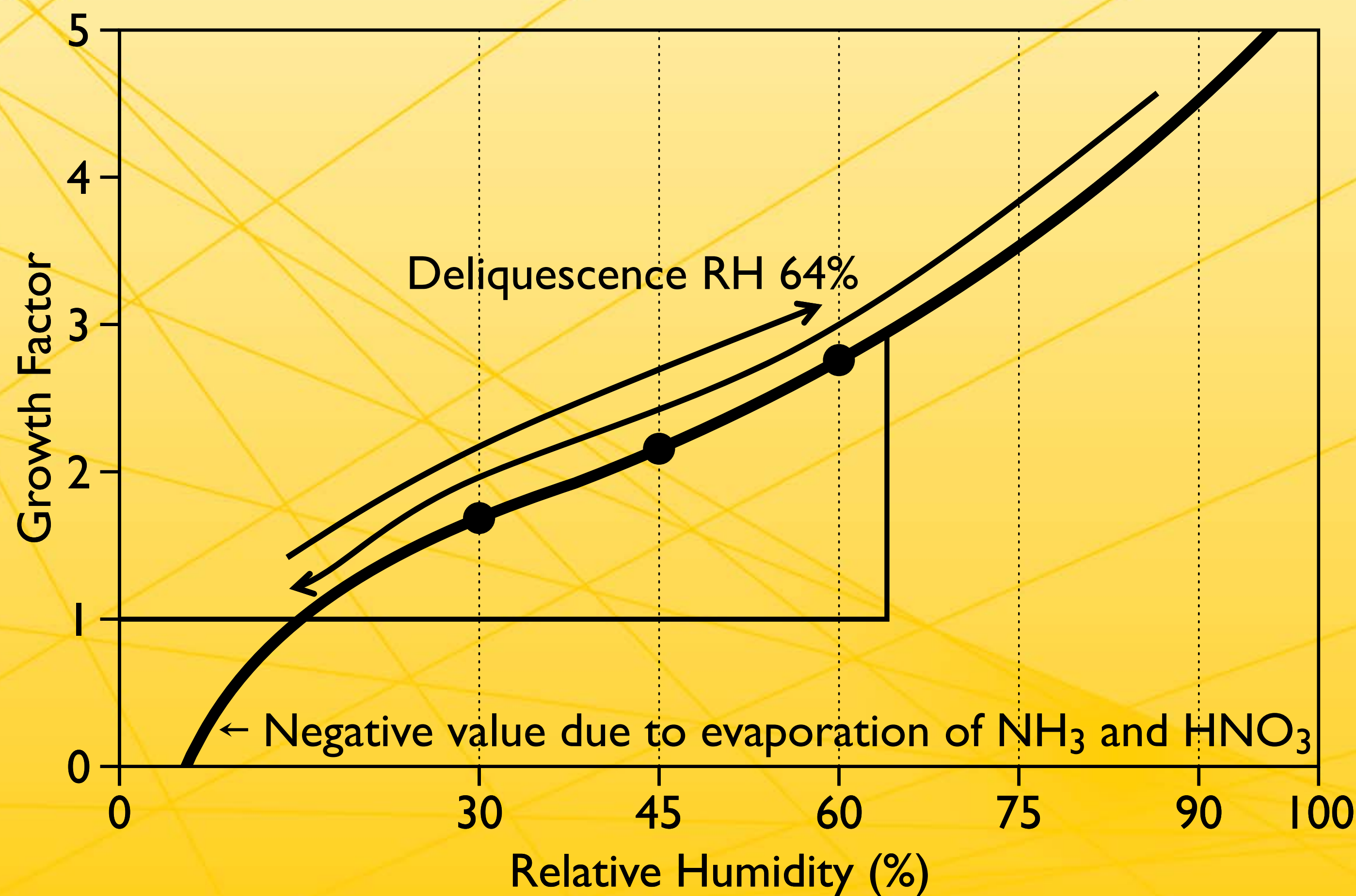
Dehydration Method 1 of NH_4NO_3



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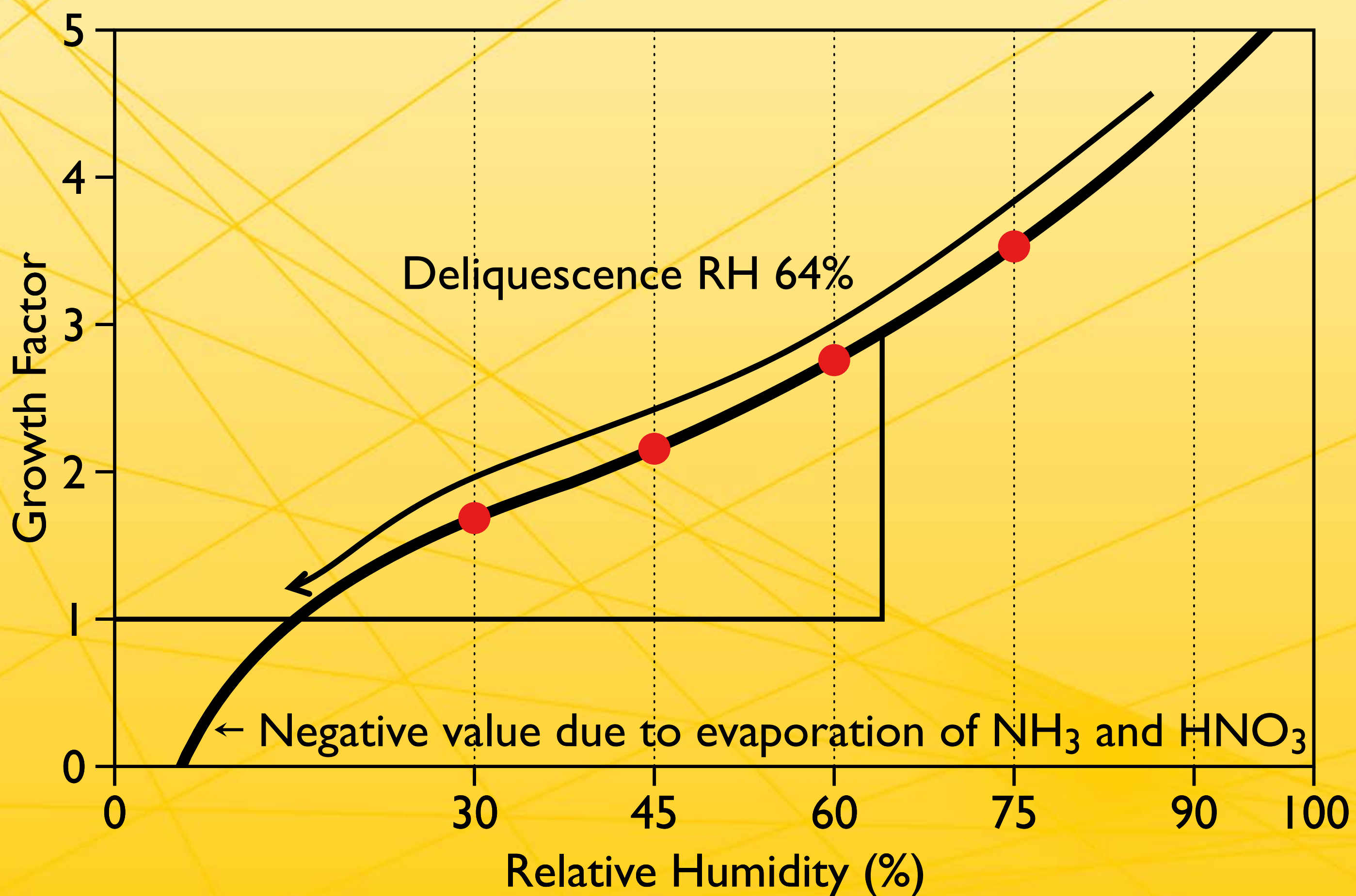
Dehydration Method II of NH_4NO_3



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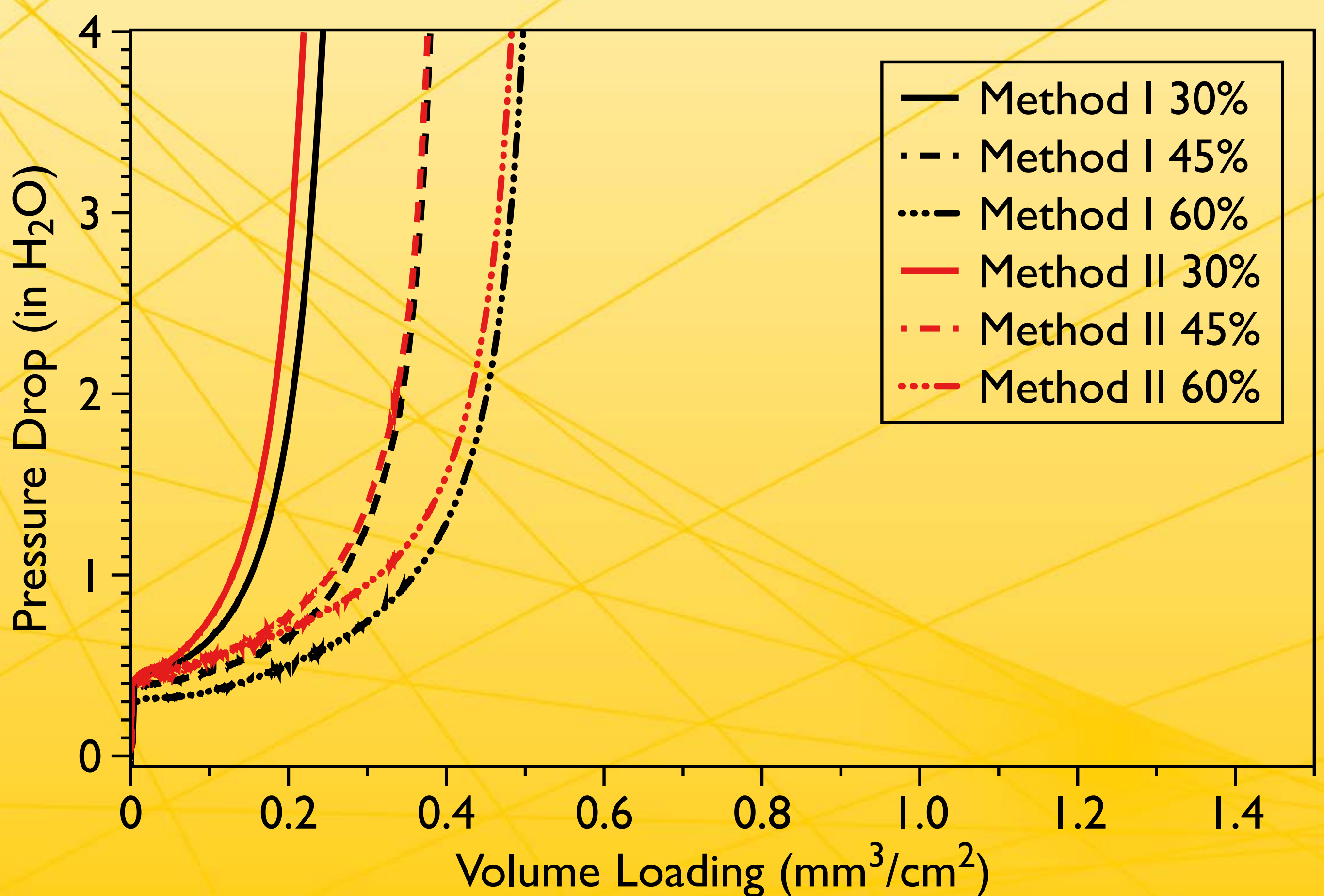
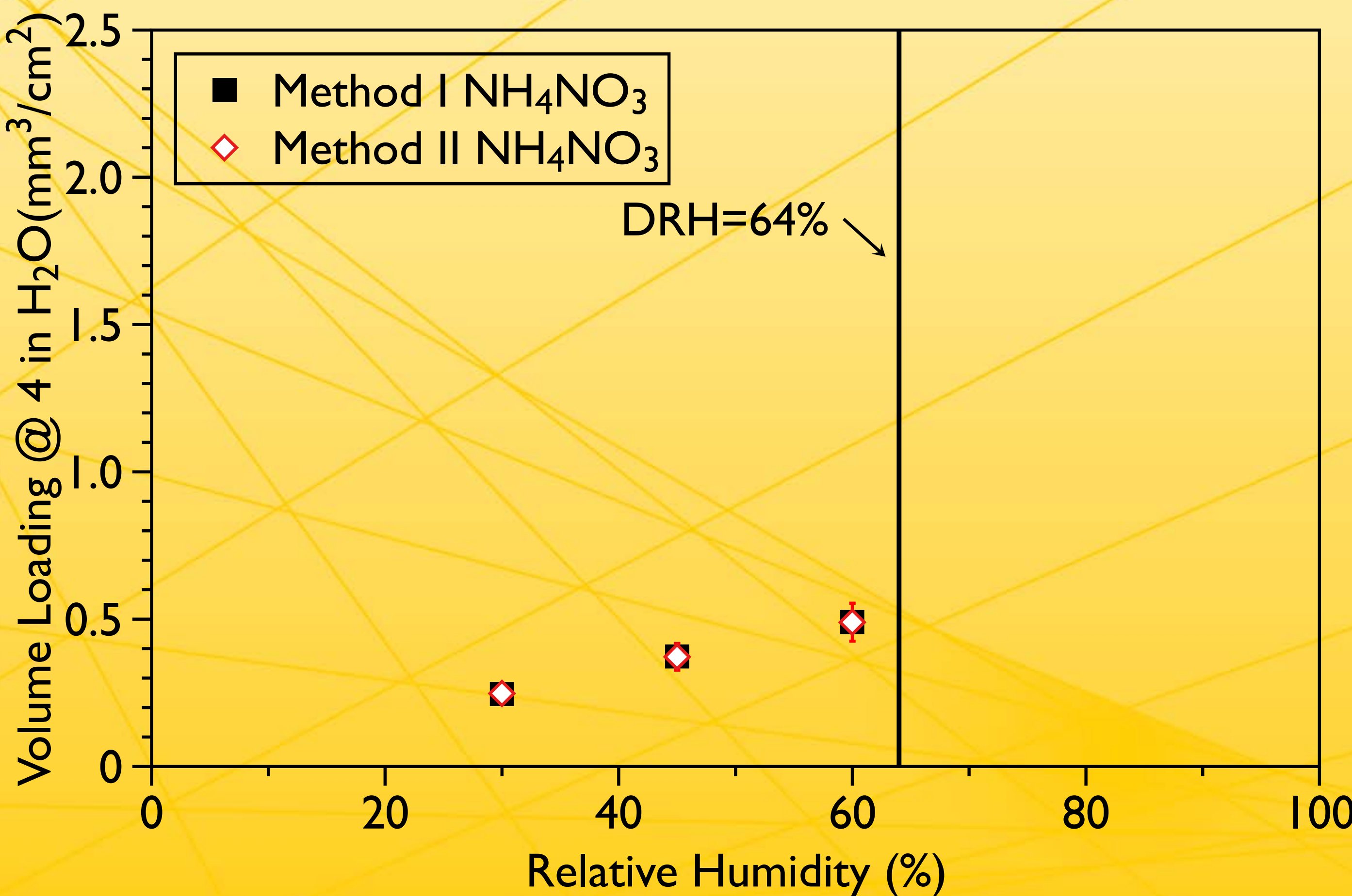
NH_4NO_3 Loading Curves



NH_4NO_3 Volume Loading @ Different RHs



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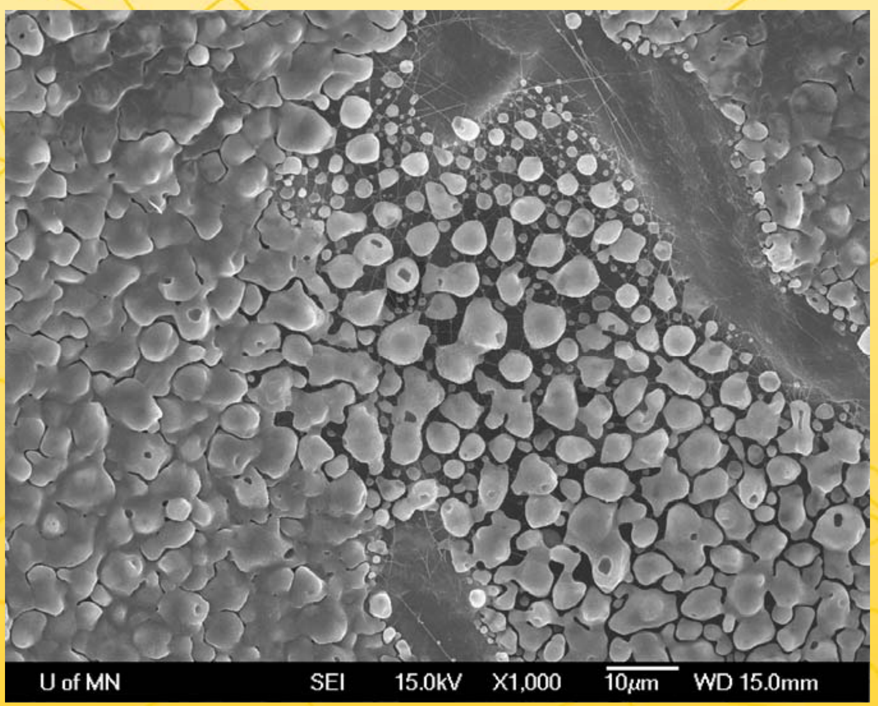
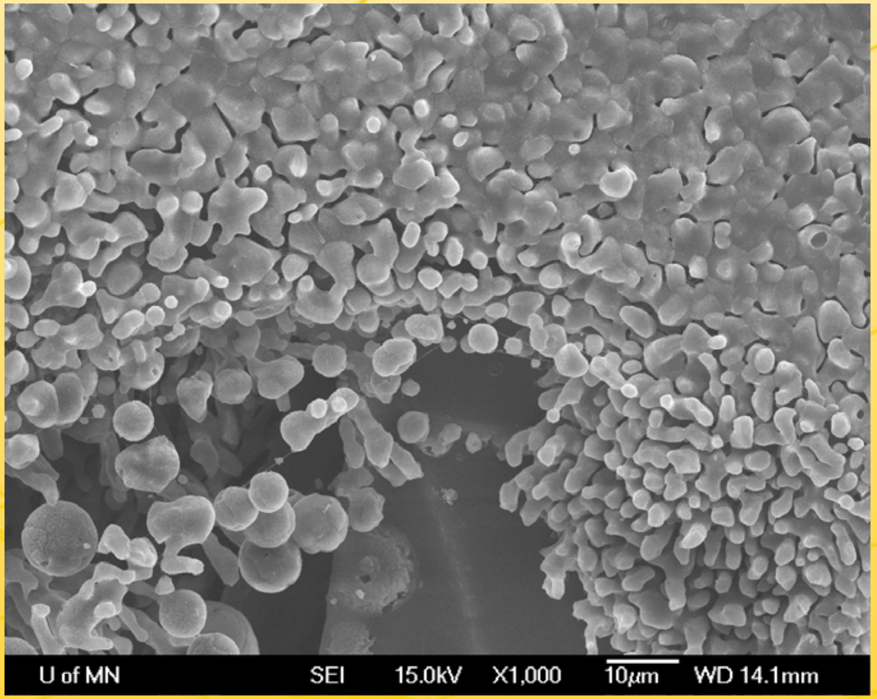
I @30%RH

II @30%RH





NH_4NO_3

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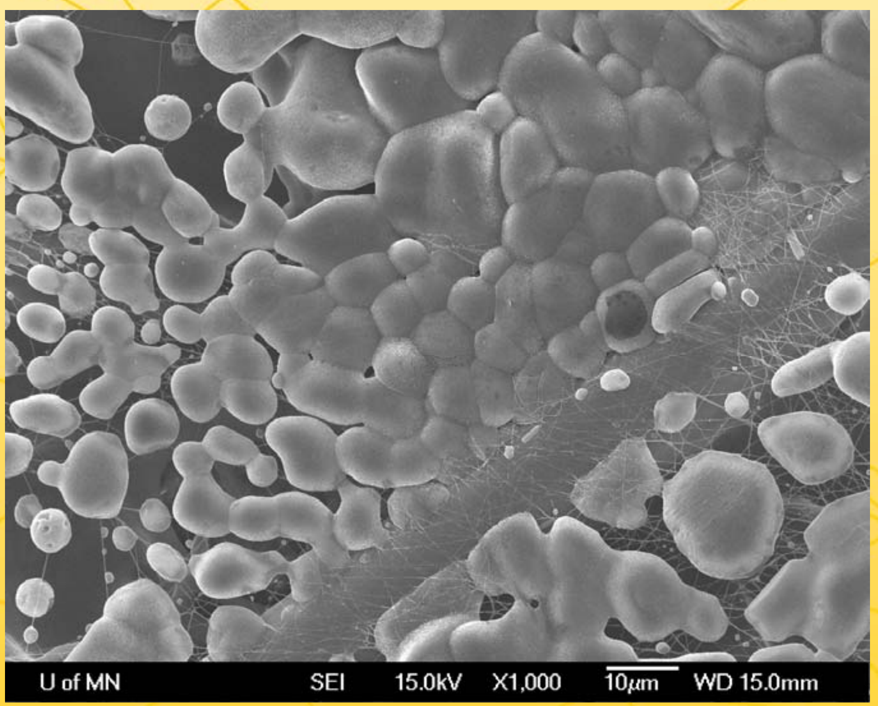
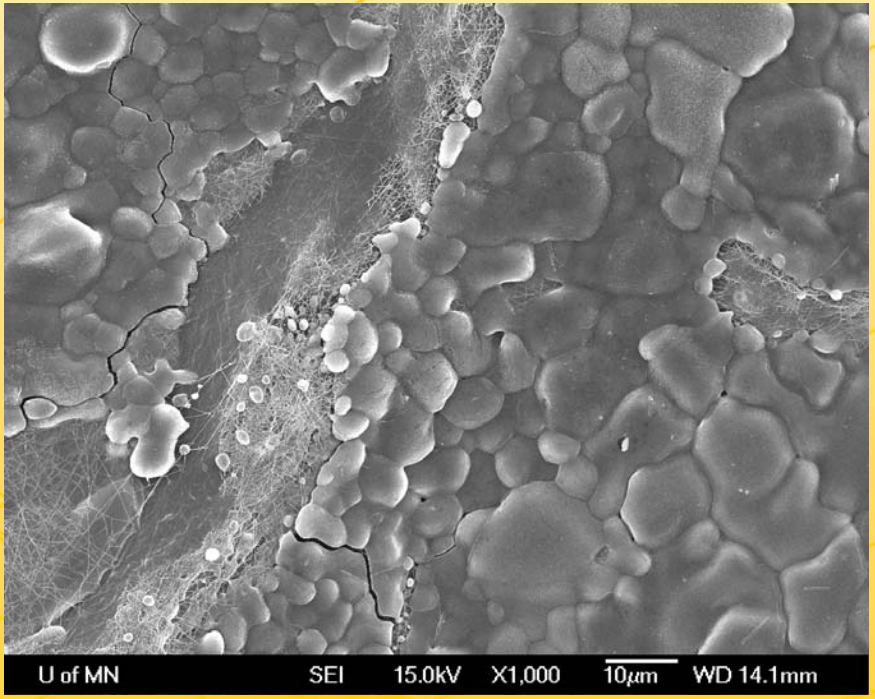
I @60%RH

II @60%RH





NH_4NO_3

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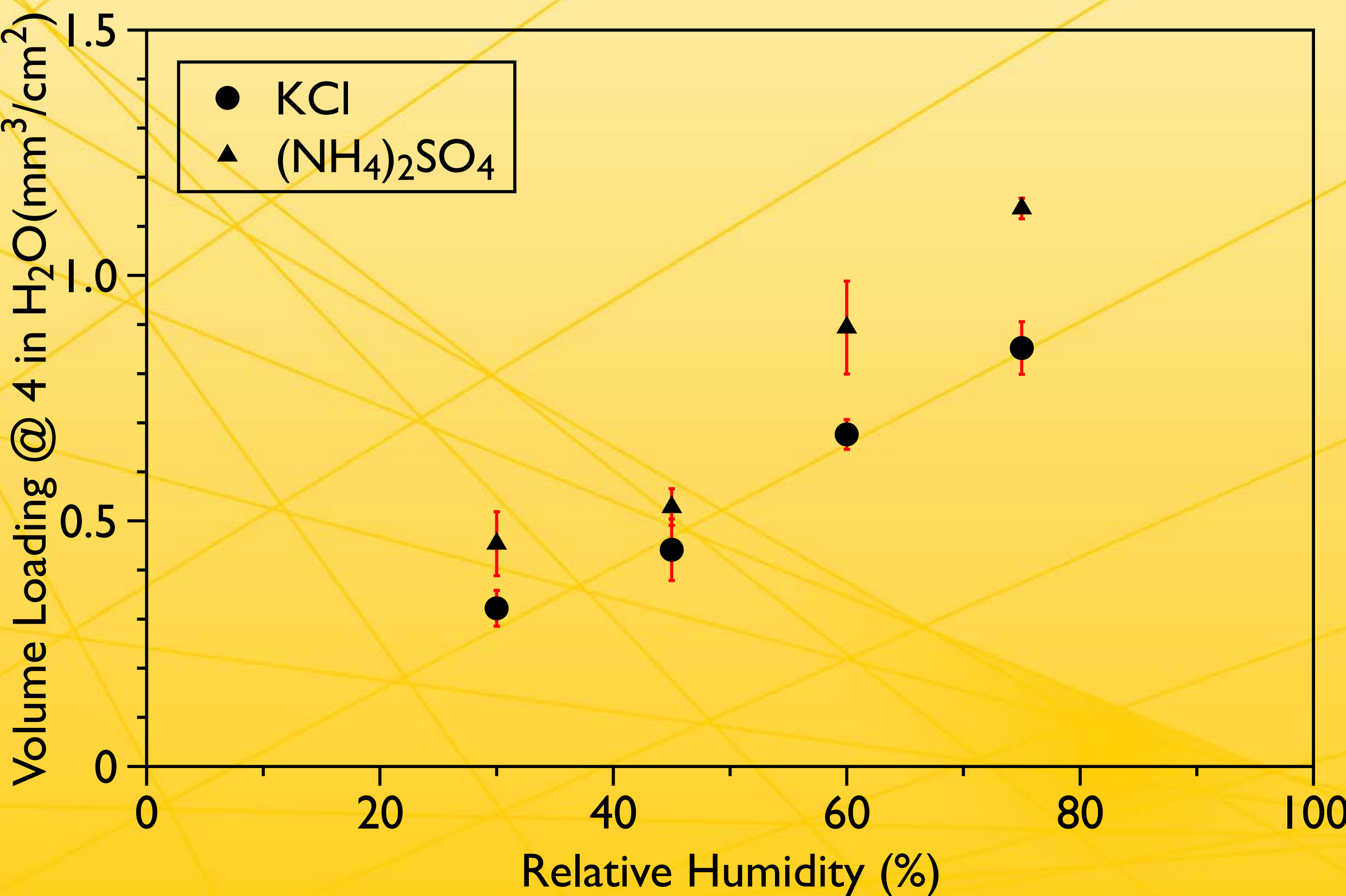
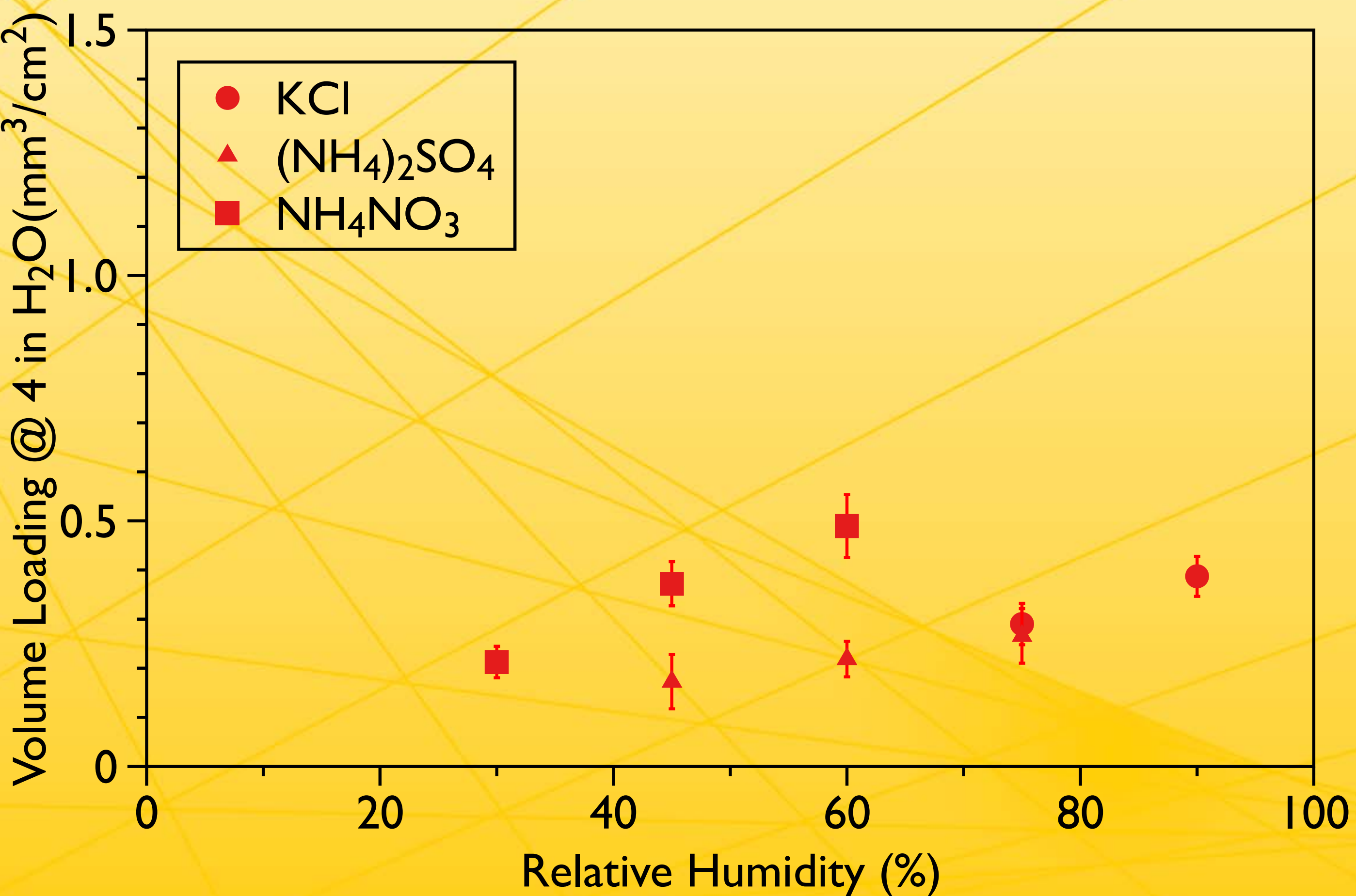
Dry KCl and $(NH_4)_2SO_4$ Volume Loading @ Different RHs



Wet KCl, $(NH_4)_2SO_4$, and NH_4NO_3 Volume Loading @ Different RHs



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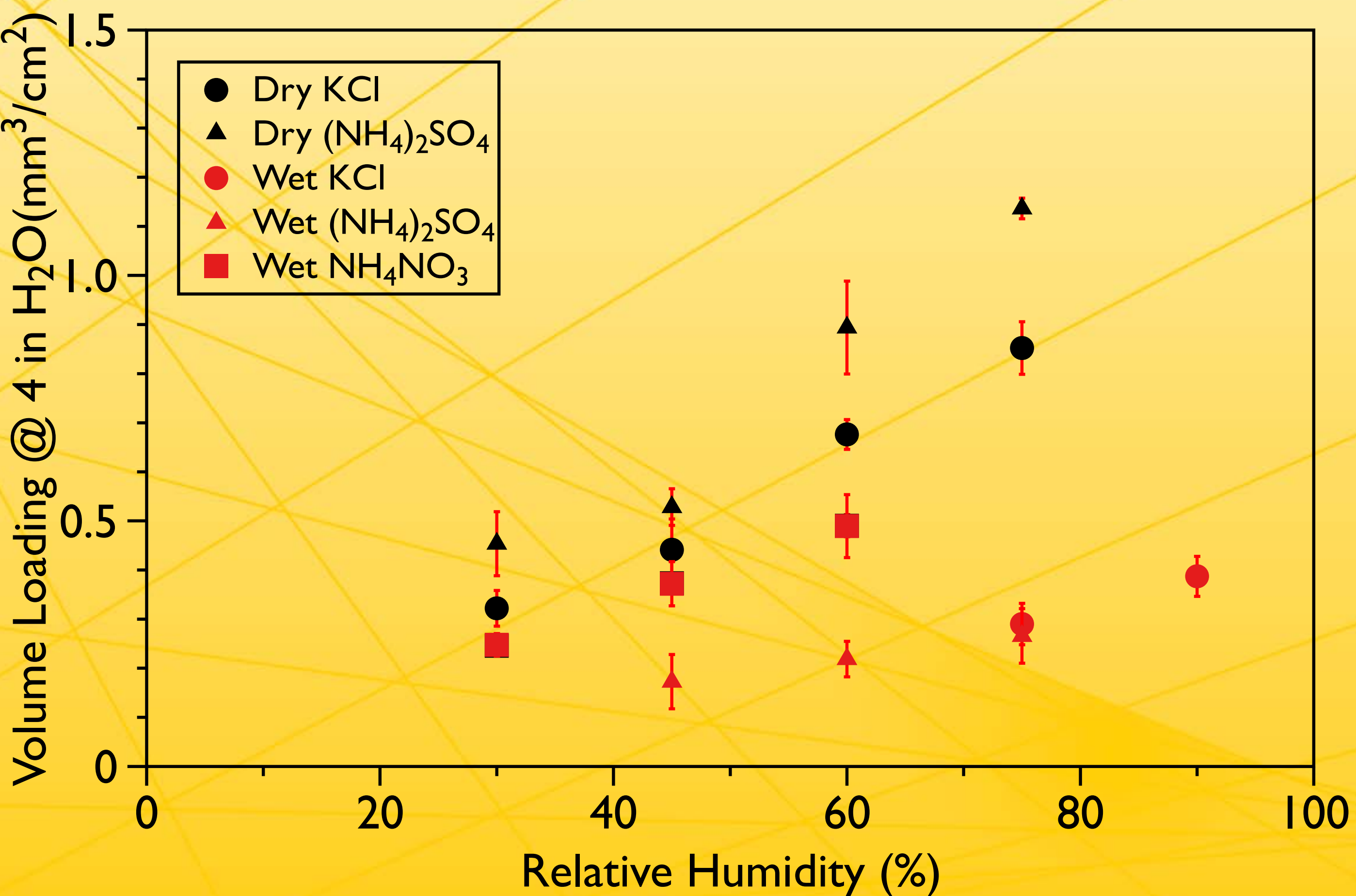
KCl, $(NH_4)_2SO_4$, and NH_4NO_3 Volume Loading @ Different RHs



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Comparison with Conventional Cellulose Filter

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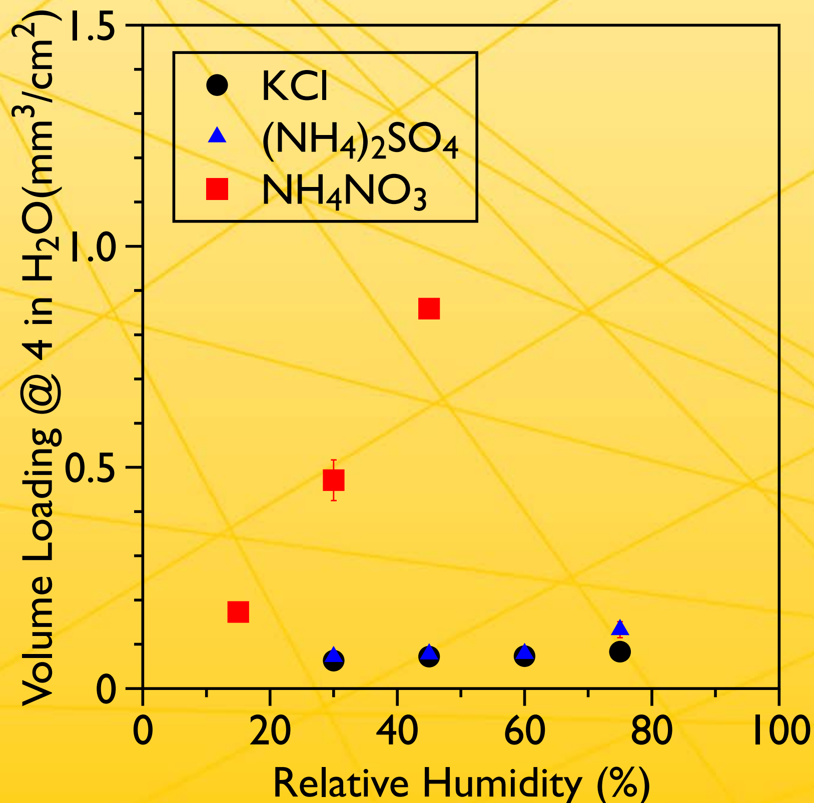
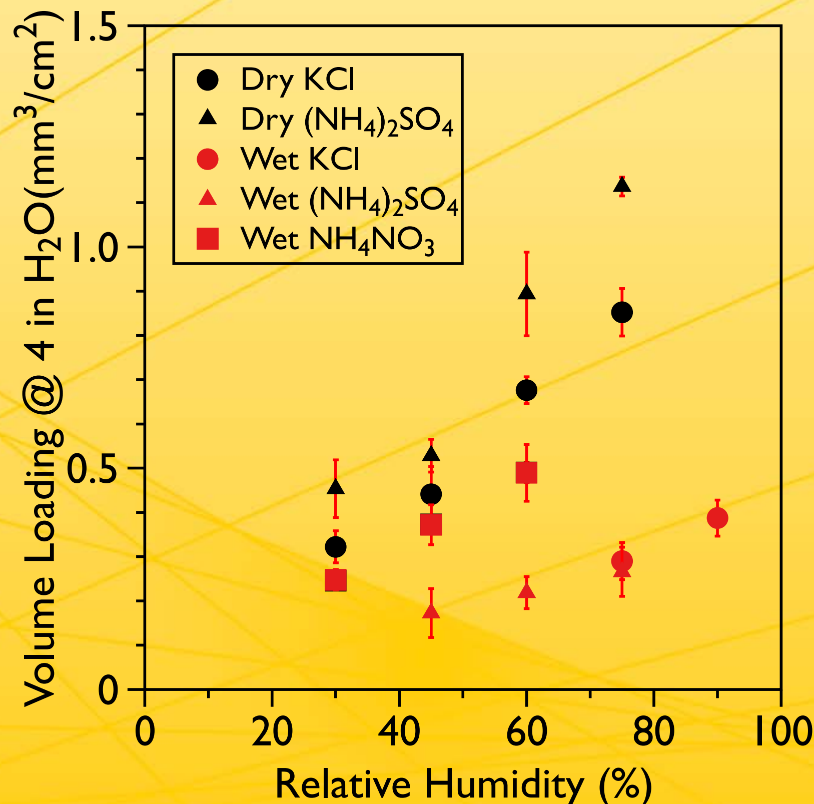
Volume Loading Comparison

Without Nano-fiber Coating



With Nano-fiber Coating



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Summary

- Loading performance is relative humidity dependent. High relative humidity results in more volume loading for both dry and wet particles
- $(NH_4)_2SO_4$ volume loading is higher than KCl in a broad relative humidity range
- Because of the incomplete dehydration, NH_4NO_3 behaves differently from both $(NH_4)_2SO_4$ and KCl
- Dry particles could load more on nanofiber coated cellulose filter, wet particles could load more on conventional cellulose filter

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Appendices

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Relevant Testing Standards

- ASHRAE 52.2:2007 Method of Testing General Ventilation Air-cleaning Devices for Removal Efficiency by Particle Size
  - *"The test aerosol shall be polydisperse solid-phase (dry)* ***potassium chloride (KCl)*** *particles generated from an aqueous solution."*
  - *"The temperature of the air at the test device shall be between 10°C and 38°C (50°F and 100°F) with* ***a relative humidity of between 20% and 65%.*** *"*

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Relevant Testing Standards

- ISO 5011:2014 Inlet air cleaning equipment for internal combustion engines and compressors -- Performance testing
  - *"The test dust to be used shall be ISO 12103 - A2 (ISO Fine) or ISO 12103 - A4 (ISO Coarse)"*
  - *"All tests shall be conducted with air entering the air cleaner at a temperature of 23 °C ± 5 °C. Tests shall be conducted at a* ***relative humidity of (55 ± 15) %****, the permissible variation at each weighing stage throughout each single test being ± 2 %."*

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Relevant Testing Standards

- EN 779:2012 Particulate air filters for general ventilation — Determination of the filtration performance
  - *"Room air or outdoor air may be used as the test air source.* ***Relative humidity shall be less than 75 %.****"*

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