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Measurement of Nitric Acid and particulate Acidity with Fabric denuders

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*University of California, Riverside  
Bourns College of Engineering*

# **MEASUREMENT OF NITRIC ACID AND PARTICULATE ACIDITY WITH FABRIC DENUUDERS**

**Dennis R. Fitz**

**An International Workshop on the Influences of Air  
Quality on the Mayan Heritage Sites in Mesoamerica**

**October 16-21, 2005**

**HN Krystal Cancun Hotel**

**Cancun, Quintana Roo, Mexico**

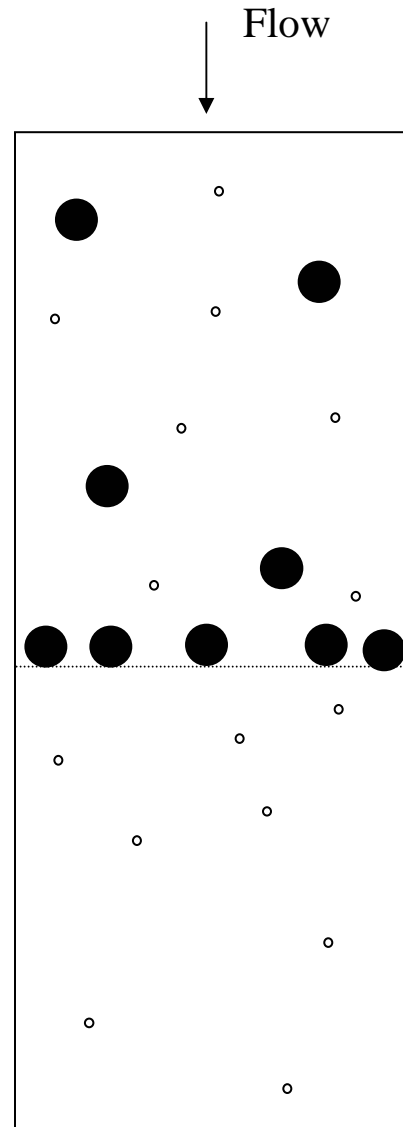
**University of California, Riverside, College of Engineering  
Center for Environmental Research and Technology  
(CE-CERT)**

*Center for Environmental Research and Technology*

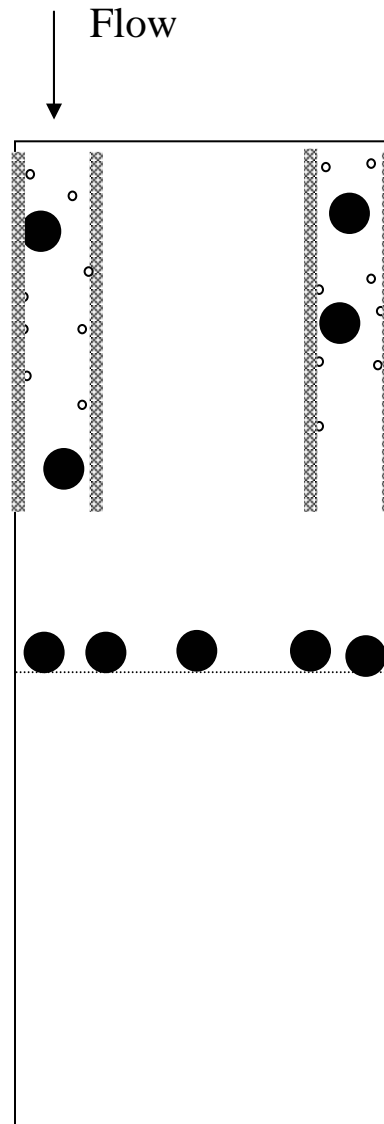
# **PRESENTATION FORMAT**

- **Denuder Theory**
- **Motivation and Objectives**
- **Theoretical Basis**
- **Laboratory Evaluation**
- **Ambient Air Evaluation**
- **Conclusions**

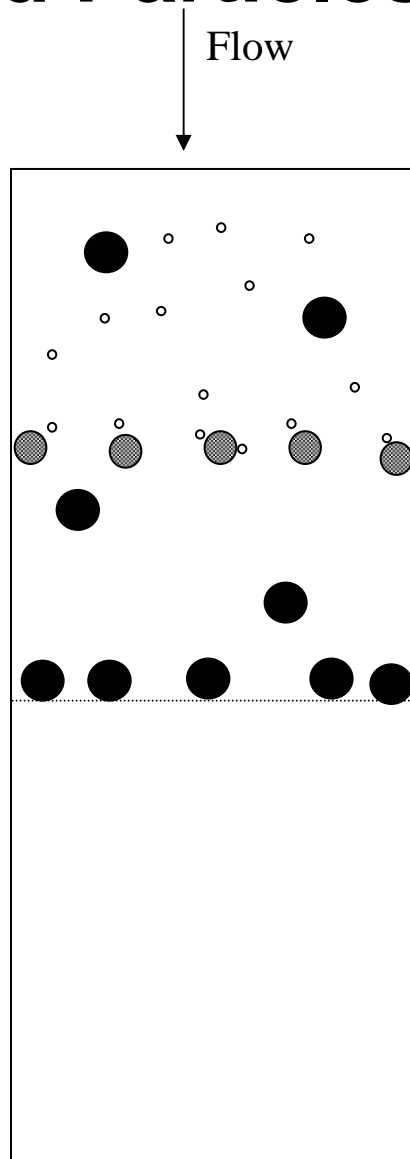
# Gases and Particles-Normal Filtration



# Gases and Particles-Annular Denuder



# Gases and Particles-Fabric Denuder



## MOTIVATION

- **Nitric acid and ammonia are important air pollutants**
- **Real-time analyzers are expensive and/or unreliable**
- **Collection methods must use diffusion denuders to avoid particulate collection**
- **Existing diffusion denuders were expensive, required skilled extraction, and were not readily adapted to different flow rates**

# **OBJECTIVES**

- **Develop a low cost denuder suitable for routine measurements of nitric acid and ammonia and preserve particulate acidity**
- **Evaluate the denuder under laboratory conditions**
- **Evaluate the denuder under ambient conditions by comparison with spectroscopic methods**



# THEORETICAL BASIS

- **Selectively adsorb gases around a fiber rather than a long channel**
- **Approach is based on diffusion batteries used to collect fine particles**
- **Diffusion batteries progressed from single channels, to multiple channels, to honeycomb, and ended with wire screens**

# THEORETICAL BASIS

- An empirical equation was used to describe particle penetration through a wire mesh
- $P = \exp(-AnPe^{-2/3})$

# THEORETICAL BASIS

$$P = \exp(-AnPe^{-2/3})$$

$$A = \frac{2\beta ah}{\pi(1-a)r} \text{ where:}$$

$$\beta = 2.7$$

a = solid surface fraction (volume solid/total volume  $\approx 0.3$  by geometry)

r = fiber radius, cm

h = screen thickness, cm

n = number of screens

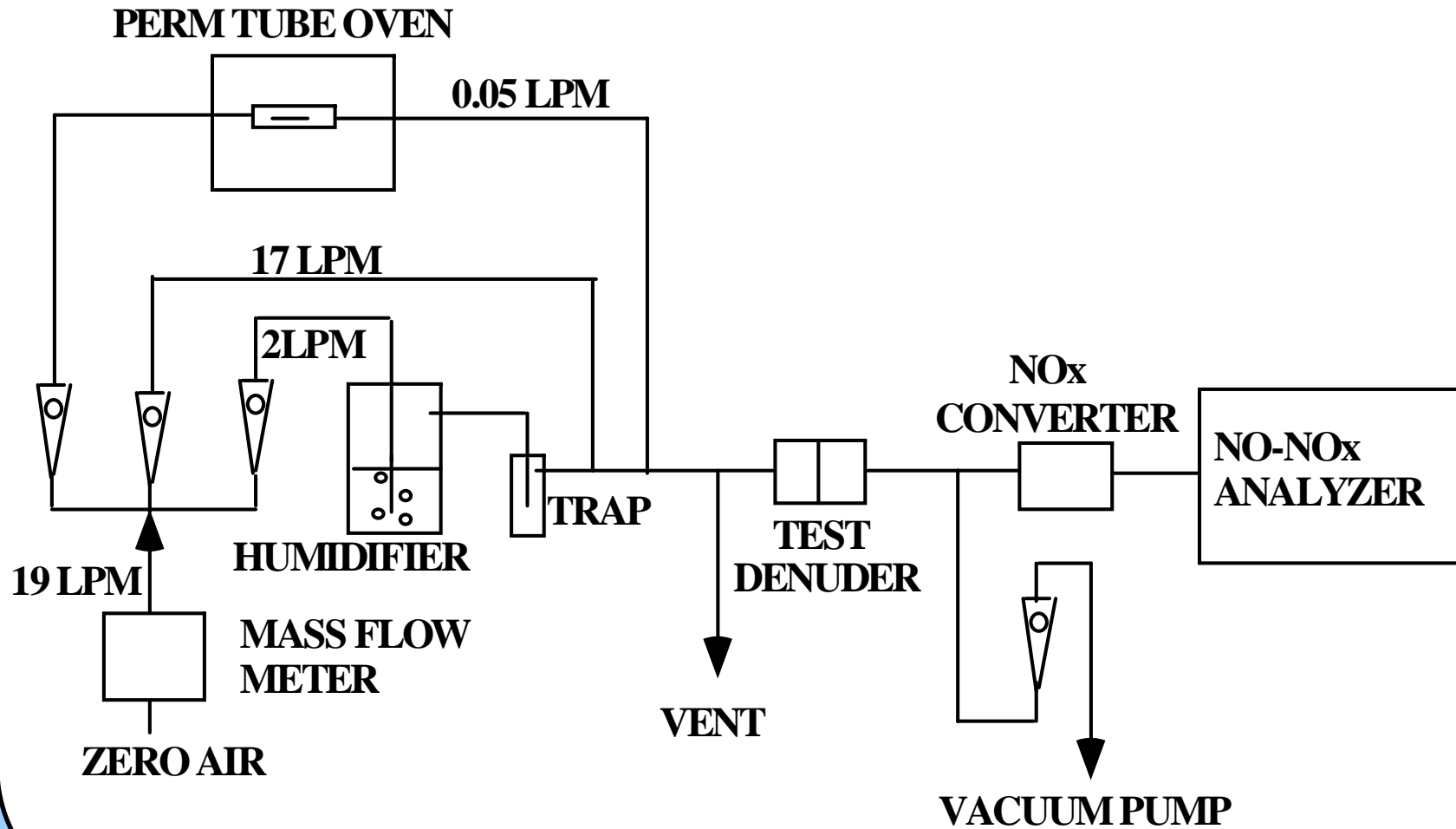
$$Pe = \text{Peclet number} = 2r U_0/D$$

where:

$U_0$  = undisturbed flow velocity,  $\text{cm sec}^{-1}$

D = Diffusion coefficient,  $\text{cm}^2 \text{sec}^{-1}$

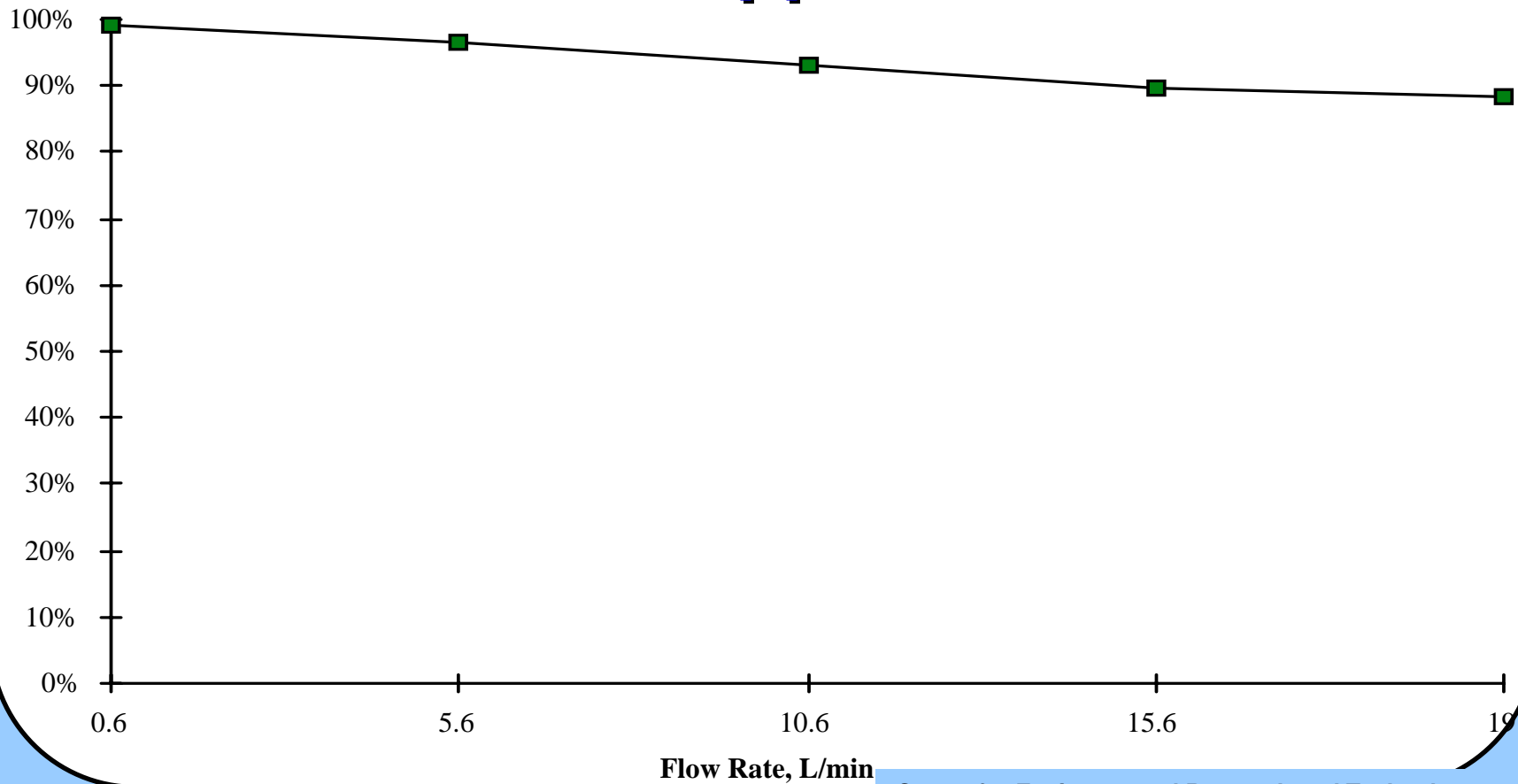
# LABORATORY EVALUATION



# THEORETICAL PENETRATION CALCULATIONS

- **Fabric grid cell is 100  $\mu\text{m}$  on 250  $\mu\text{m}$  centers**
- **4.0 cm diameter fabric @ 10 L/min**
- **Nitric acid ( $D = 0.12 \text{ cm}^2/\text{sec}$ )**
  - »  **$P = 0.02$**
- **0.1  $\mu\text{m}$  Particle ( $D = 6 \times 10^{-6} \text{ cm}^2/\text{sec}$ )**
  - »  **$P > 0.99$**

# Laboratory Testing Sodium Carbonate Coating Observed Nitric Acid Removal Efficiency- 35ppb



## **LABORATORY EVALUATION**

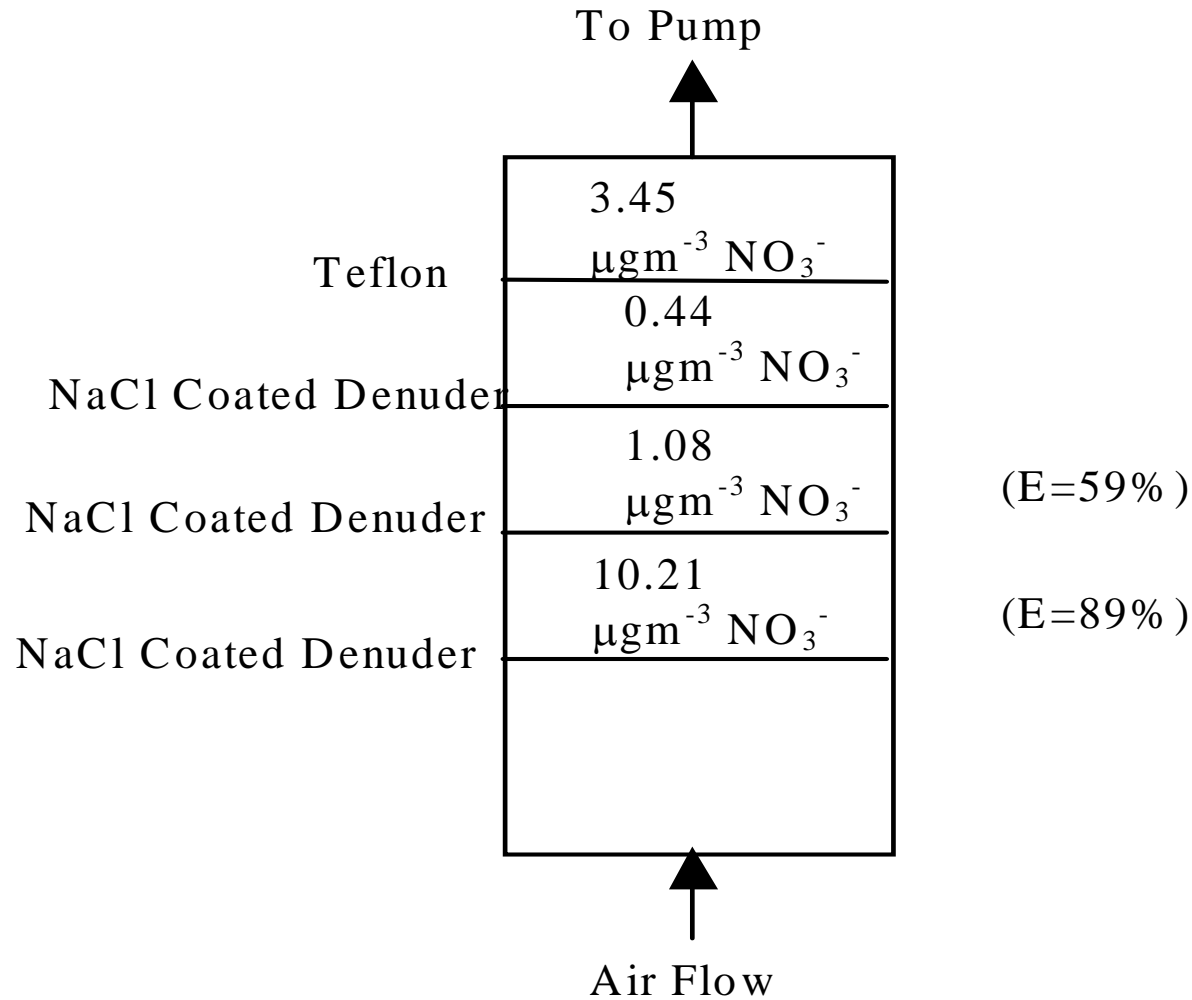
- **Nitric acid removal efficiency was tested for over 20 types of fabric materials using a coating mixture of 9% NaCl (w/w) in a methanol/water solvent (50/50 v/v)**
- **The four materials with the highest nitric acid efficiency were evaluated sampling ambient air.**
- **These four were also tested in the laboratory for ammonia removal efficiency using a phosphoric acid coating (9% v/v)**

# CALCULATED COLLECTION EFFICIENCY FROM SERIES SAMPLING (%)

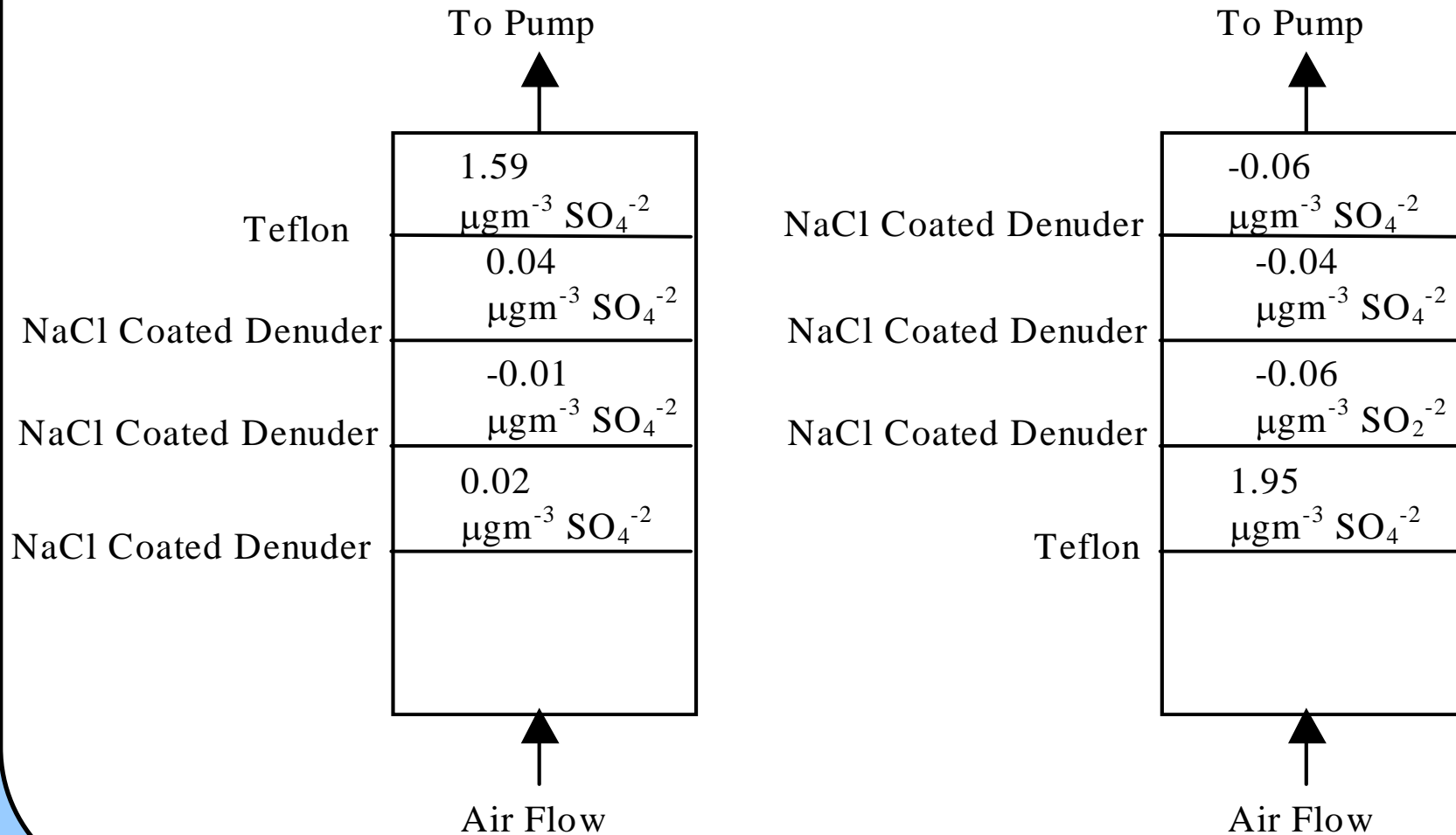
- $E = [1 - (C_b / C_f)] * 100$ 
  - $C_f$  is the concentration on the front denuder
  - $C_b$  is the concentration on the back denuder



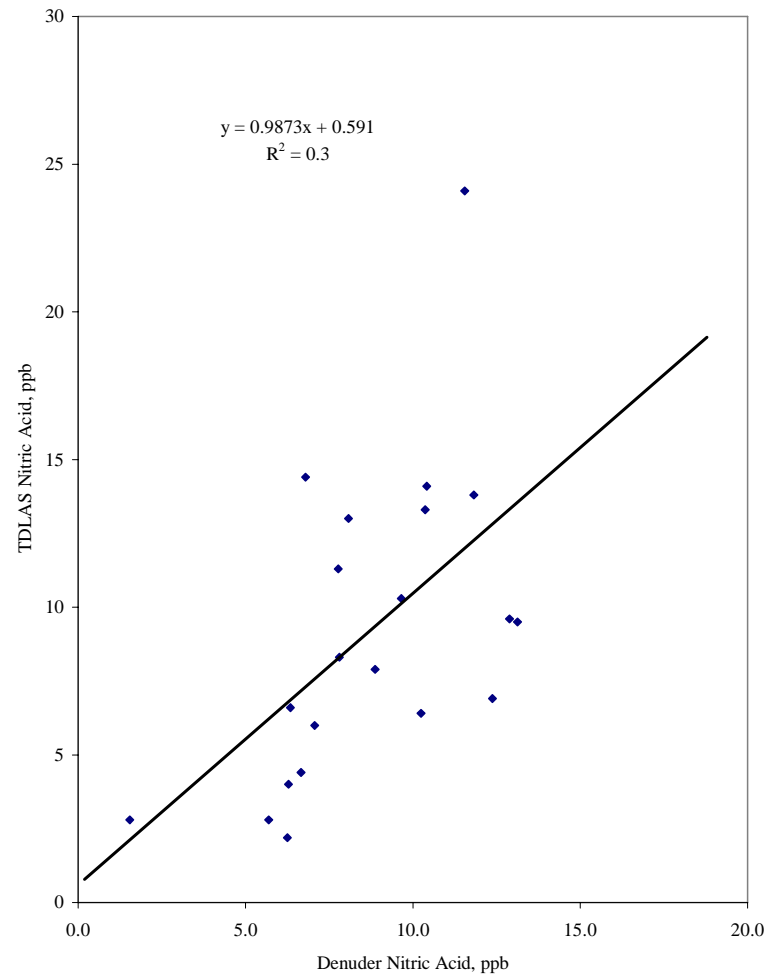
# AMBIENT EVALUATION NITRIC ACID COLLECTION 10 L/MIN



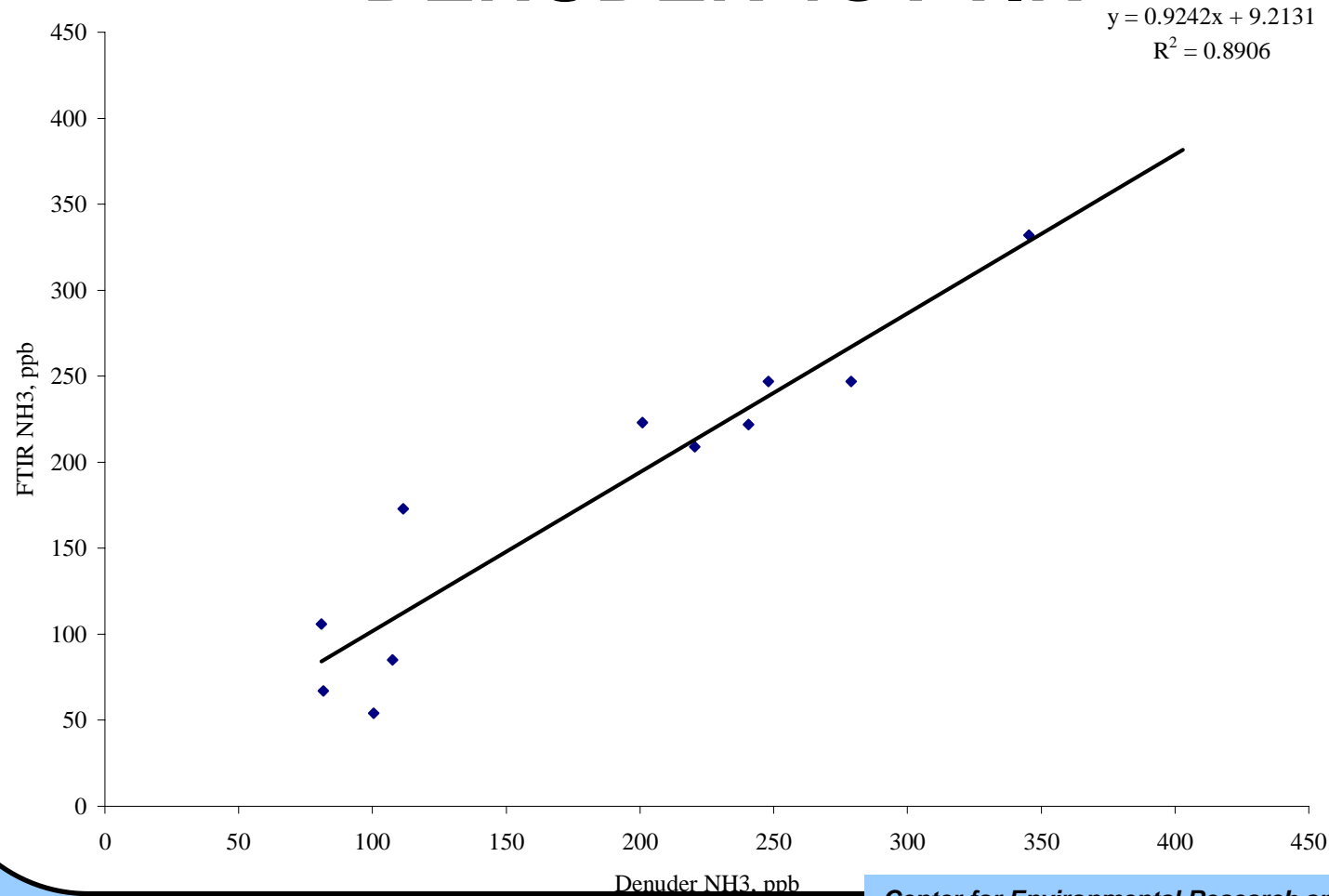
# AMBIENT EVALUATION SULFATE COLLECTION 10 L/MIN



# AMBIENT EVALUATION NaCl COATED FABRIC DENUDER vs TDLAS



# AMBIENT EVALUATION PHOSPHORIC ACID COATED FABRIC DENUDER vs FTIR



## **CONCLUSIONS**

- **The fabric denuder is a low cost effective method of sampling nitric acid and ammonia and preserving particulate acidity**
- **The ambient evaluations were conducted under worst case conditions where high ammonium nitrate levels are observed**