SILENCING THE NOISE:
NEW TECHNOLOGY TO OBTAIN TIME-INTEGRATED AVERAGE GROUNDWATER CONCENTRATION OVER MONTHS

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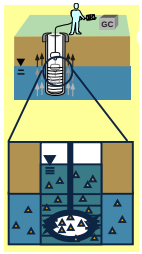

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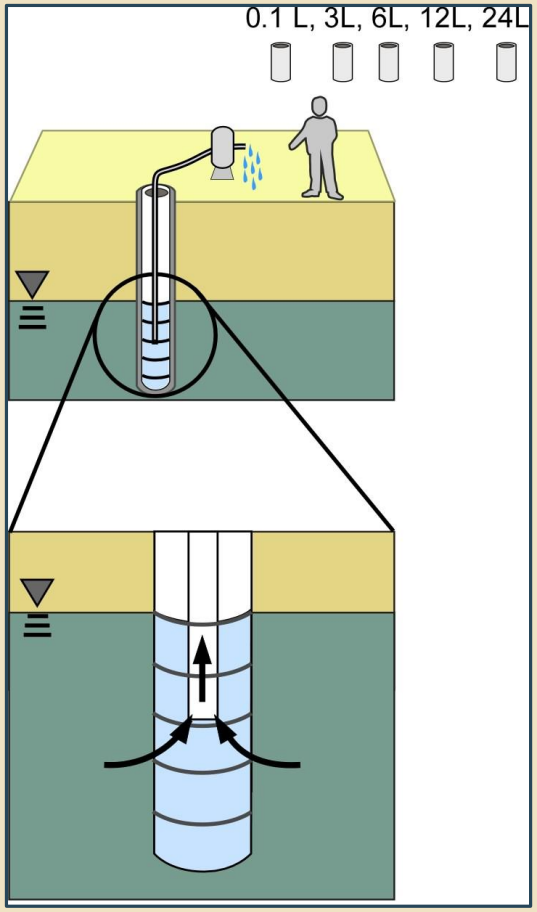
EMDQ Workshop, Phoenix, AZ, April 2017

INTRODUCTION

HOW DO WE CURRENTLY MONITOR CONTAMINATED GROUNDWATER?

INTRODUCTION

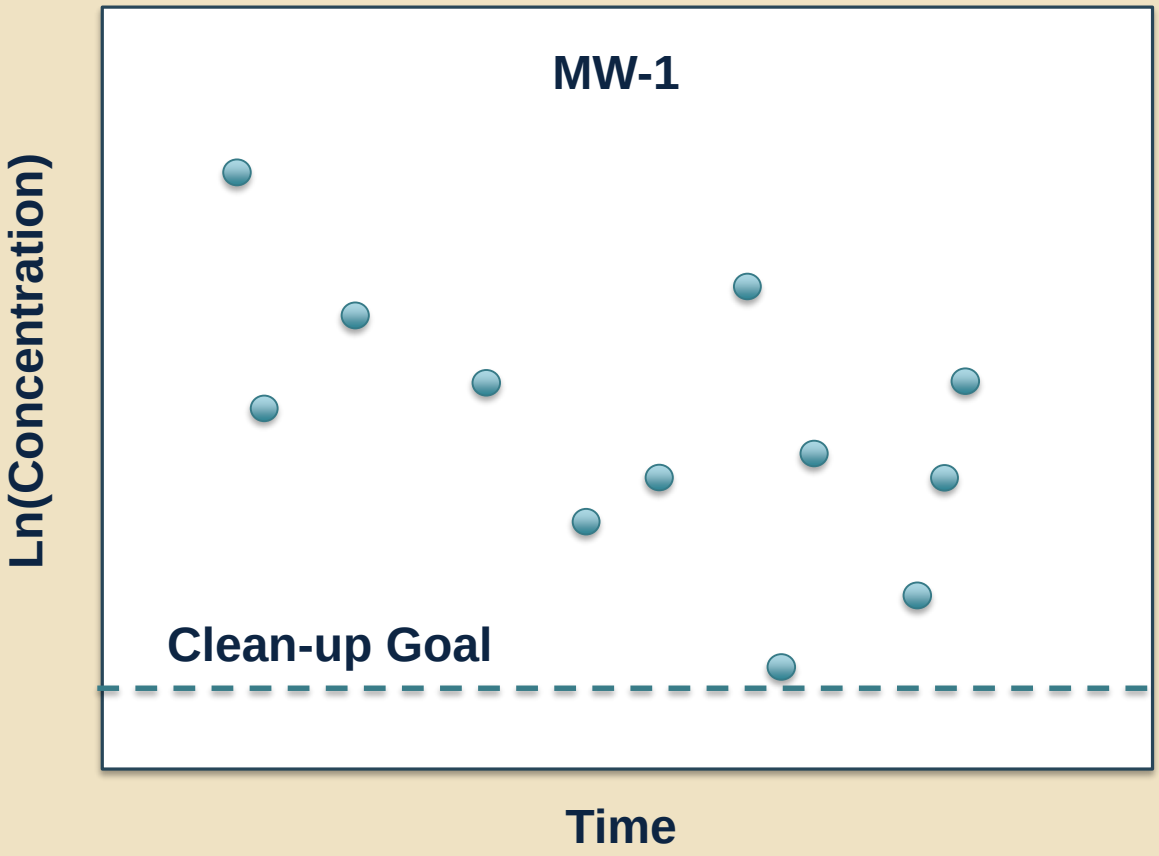
How do we collect groundwater samples?



- Use pump (or other device) to collect water sample from well
  - Time consuming
  - Purge waste
- Send water sample to laboratory for analysis
  - Requires cooler with ice
  - Heavy, expensive, time sensitive

INTRODUCTION

What do we get: Noisy Data



Decreasing concentrations?

INTRODUCTION

Problems with current monitoring methods?

- **Sample collection is expensive and time consuming**
- **Significant event-to-event variability in monitoring results (i.e. data is noisy)**
  - **Grab samples are problematic**

INTRODUCTION

CAN WE DEVELOP A SAMPLER THAT IS EASIER TO USE AND PROVIDES BETTER DATA?

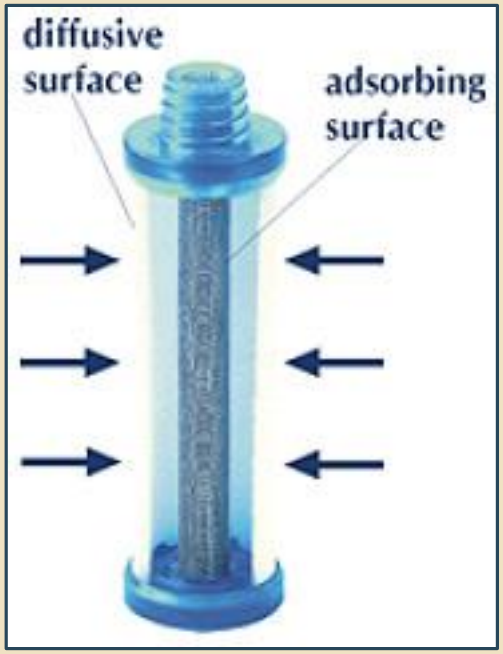
Goals?

1) Ease of use
2) Lower cost
3) Minimize data variability

EXAMPLES OF TIME-INTEGRATED SAMPLERS

Air / Soil Gas

- **Passive sorbent samplers commonly used to collect 7-day average VOC concentrations.**
- **Can be deployed for as long as one year for some VOCs (USEPA, 2012).**

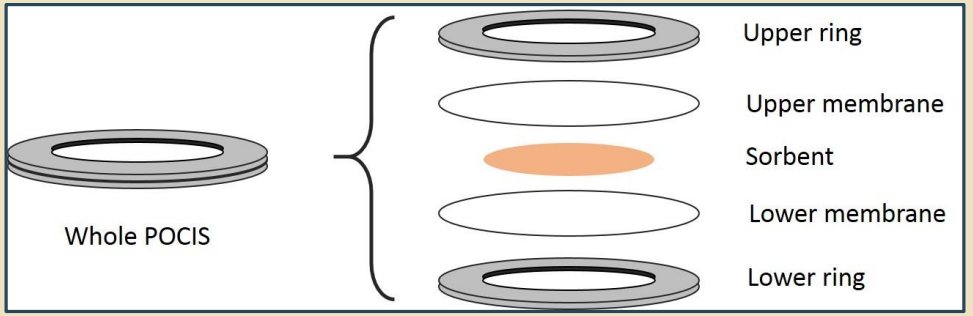


USEPA (2012), Fluctuation of Indoor Radon and VOC Concentrations Due to Seasonal Variations, EPA/600/R-12/673 | September 2012 | www.epa.gov/research

EXAMPLES OF TIME-INTEGRATED SAMPLERS

Sediment

- **Sorbent samplers increasingly used for integrated sampling of sediments.**
- **Example: POCIS – Polar Organics Contaminant Integrated Sampler (Developed by USGS).**



INTRODUCTION

WHAT ALTERNATIVES TO GRAB SAMPLES ARE CURRENTLY USED FOR GROUNDWATER?

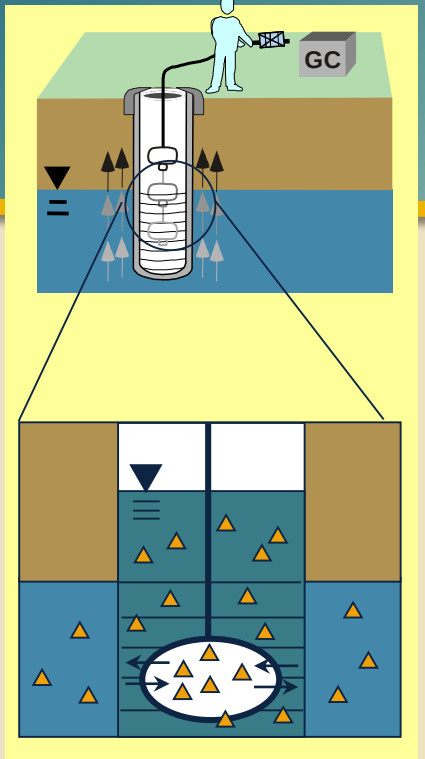
DIFFUSION SAMPLERS FOR GROUNDWATER

Passive Diffusion Bag

- Equilibration between well and water inside diffusion bag (Church, 2002)

Passive Vapor Diffusion

- Equilibration between well and air inside diffusion bag (Adamson, 2012)



Passive Diffusion Sampler

KEY POINT: ***14-day equilibration time. Not a grab sample but not a true time-integrated sample.***

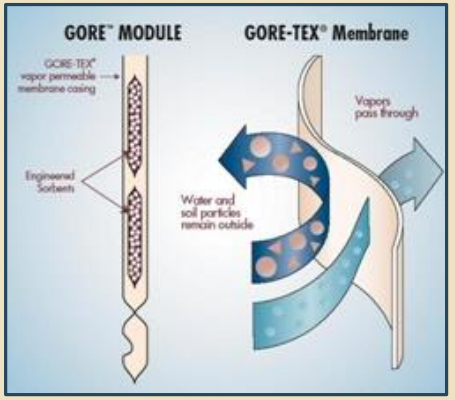
Church, P.E., D.A. Vroblesky, F.P. Lyford, and R.E. Willey. 2002. Guidance on the use of passive-vapor-diffusion samplers to detect volatile organic compounds in ground water-discharge areas, and example applications in New England. USGS Water- Resources Investigations Report 02-4186. Reston, Virginia: USGS.

David T. Adamson, Thomas E. McHugh, Michal W. Rysz, Roberto Landazuri, and Charles J. Newell, Field Investigation of Vapor-Phase-Based Groundwater Monitoring, Ground Water Monitoring & Remediation 32, no. 1/ Winter 2012/pages 59–72

SORBENT SAMPLERS FOR GROUNDWATER

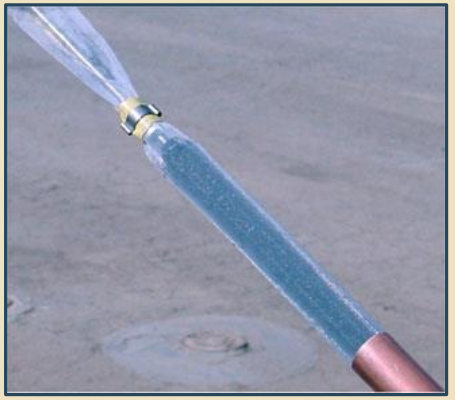
Gore Sorber

- **High uptake rate limits deployment time to hours**



Enviroflux

- **Measures contaminant flux through well (additional measurement needed to estimate concentration)**
- **Potential for biofouling of sorbent limits deployment time to a maximum of 28 days.**



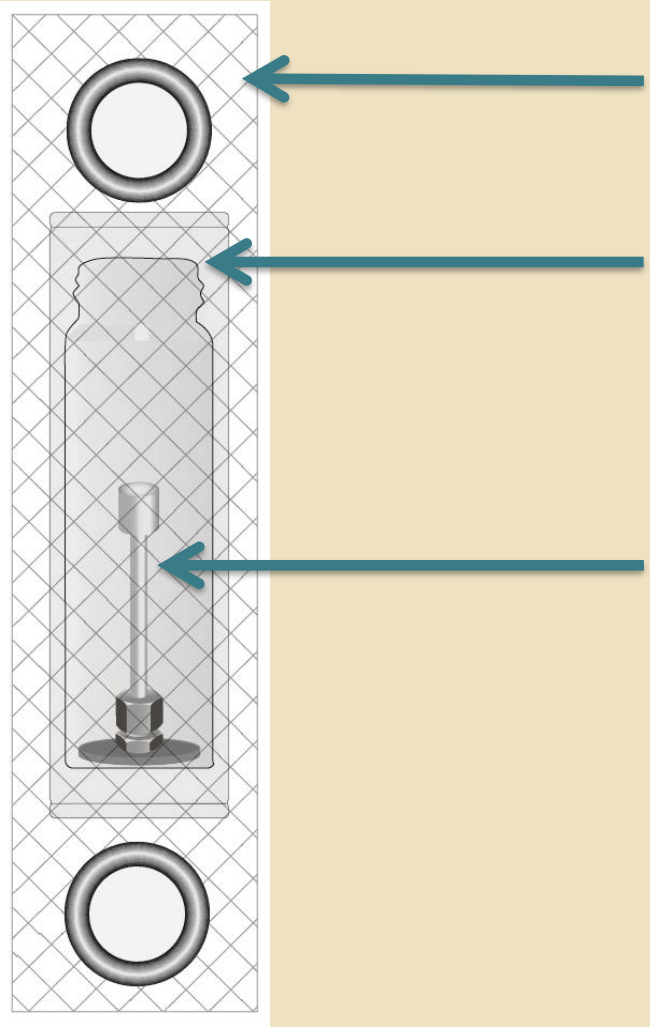
KEY POINT: ***Existing sorbent samplers have limitations that prevent long-term deployment (weeks to months).***

INTRODUCTION

TIME-INTEGRATED SAMPLER

LET'S COMBINE A PASSIVE SORBENT SAMPLER WITH AN EQUILIBRIUM SAMPLERS TO GET THE BEST OF BOTH WORLDS

TIGER SAMPLER: DESIGN



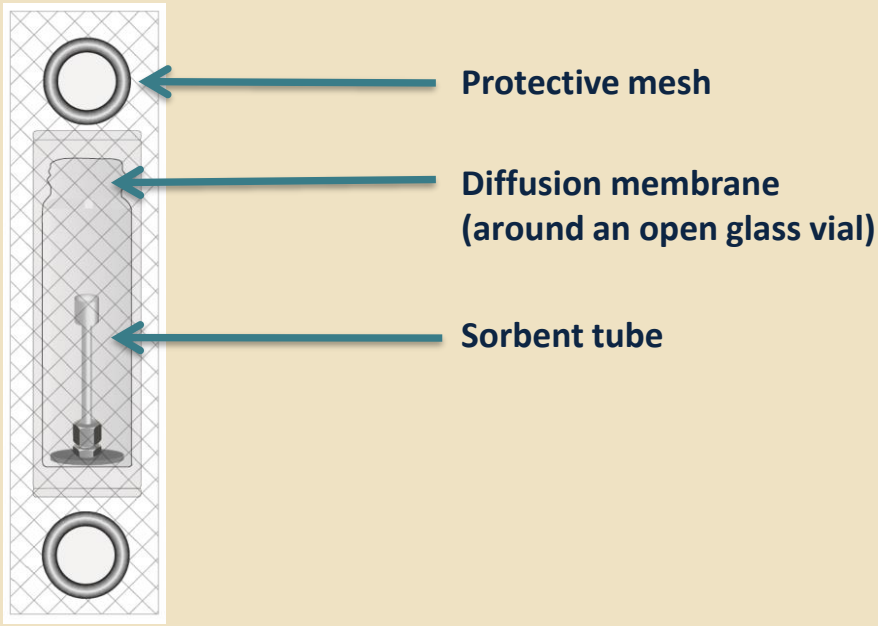
1) Protective outer mesh
   - Same mesh used to protect PDB

2) Outer diffusion membrane
   - Same material as PDB
   - Inner chamber is filled with air instead of water

3) Sorbent tube
   - Adsorbs VOCs from inner chamber

PDB = Passive Diffusion Bag; VOCs = Volatile organic compounds.

TIGER SAMPLER: THEORY



How it Works

- Outer membrane allows rapid equilibration between groundwater sampler chamber
- Low uptake rate kinetic sampler does not disrupt equilibrium and allows long deployment times

Problems Solved:

Biofouling: Sorbent is protected from groundwater

Saturation: Uptake rate can be set to allow for long deployment times without saturation of sorbent

LABORATORY VALIDATION

DOES THE SAMPLER WORK? (IN THE LABORATORY)

RICE

LABORATORY VALIDATION

Validation Program

1) Construct test tank with contaminated water
   - Tetrachloroethene (PCE)

2) Deploy samplers (duplicate pairs)
   - 2 days, 4 days, 8 days

3) Measure PCE
   - PCE concentration in water
   - PCE mass on samplers

LABORATORY FAILURES

Experiment 1

- Its HARD to get PCE to dissolve in water

Experiment 2

- Its REALLY HARD to get PCE to dissolve in water

LABORATORY SUCCESSES

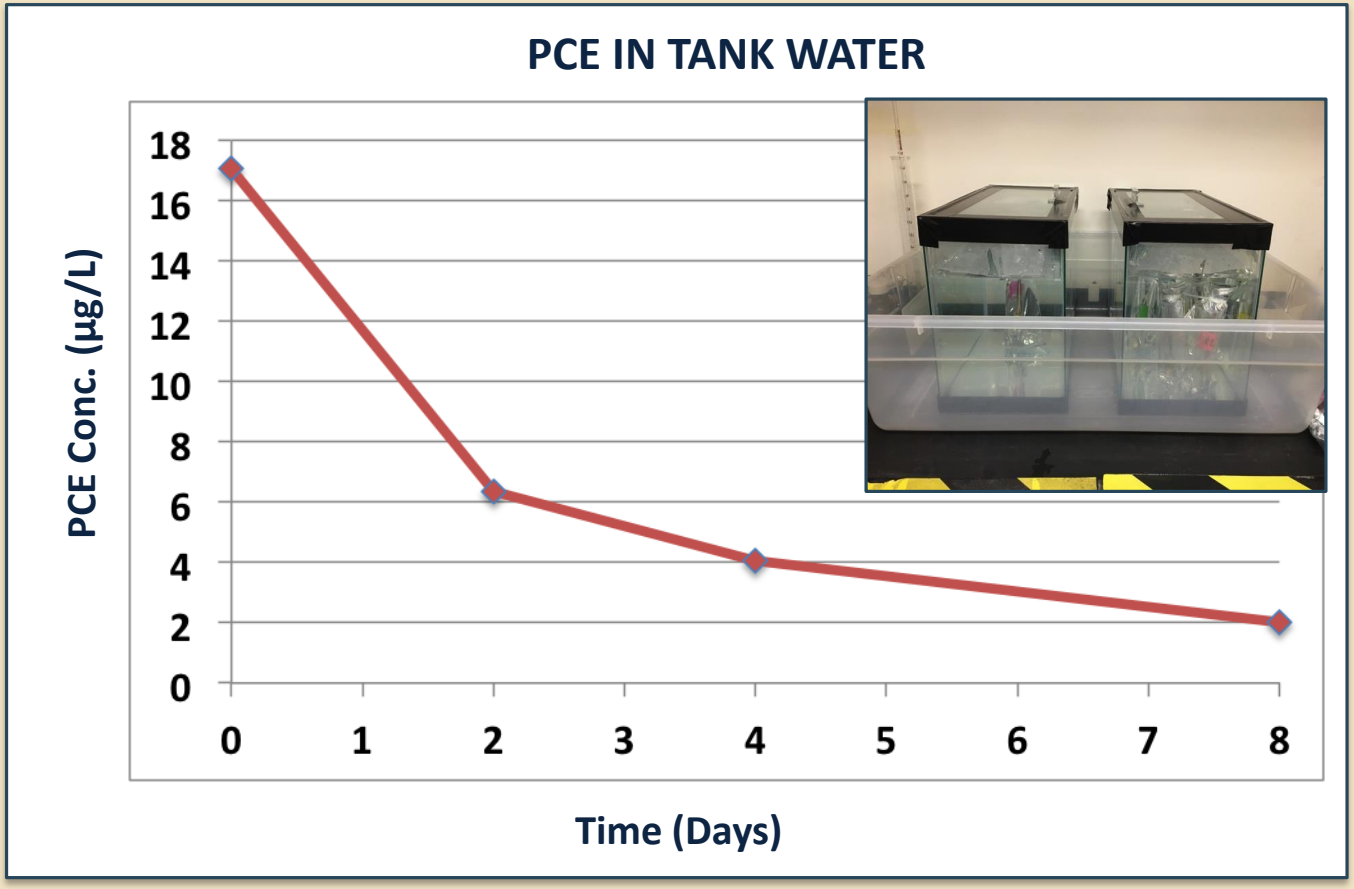
Experiment 3

- High uptake kinetic sampler (0.5 mL/min)

Experiment 4

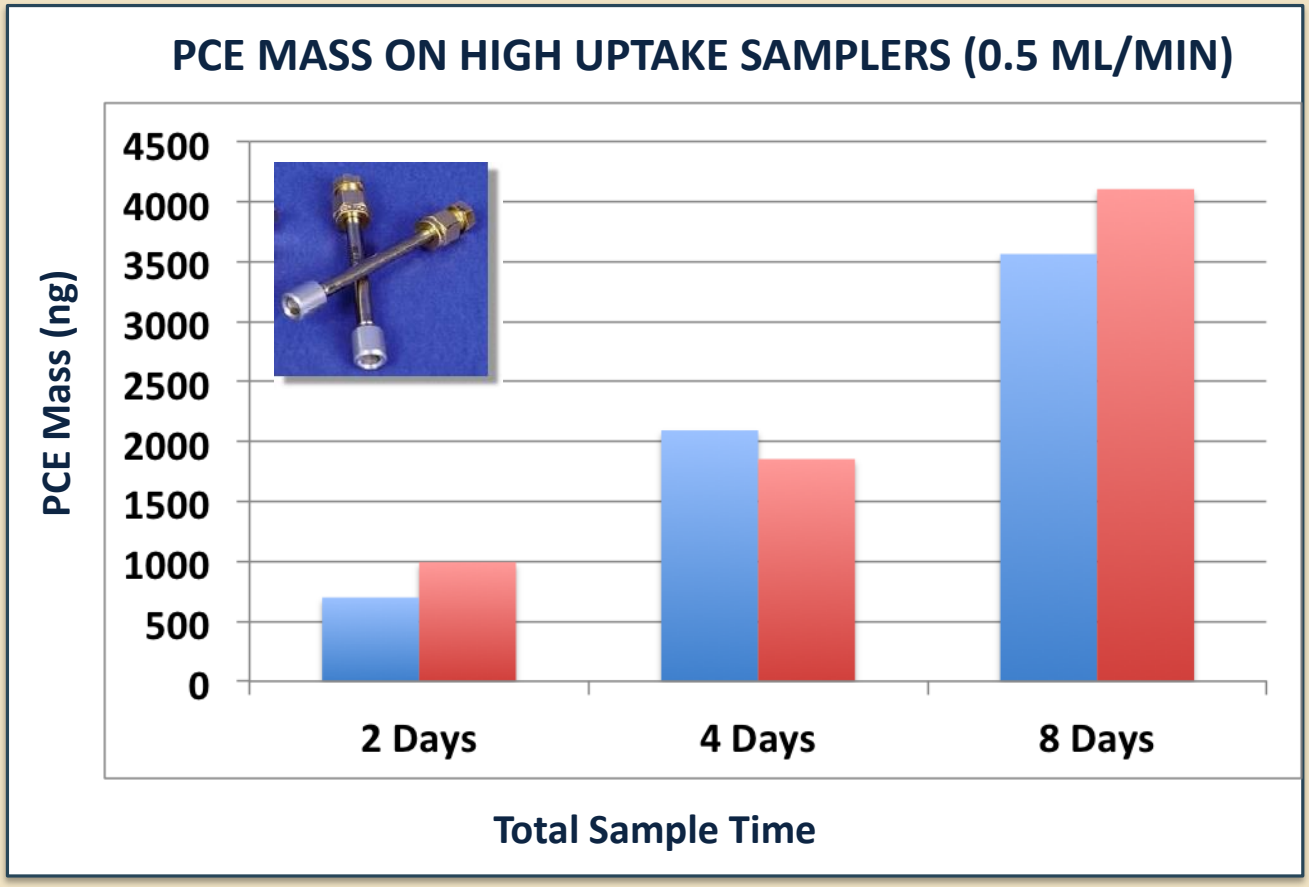
- Low uptake kinetic sampler (0.001 mL/min)

EXPERIMENT 3: HIGH UPTAKE SAMPLER



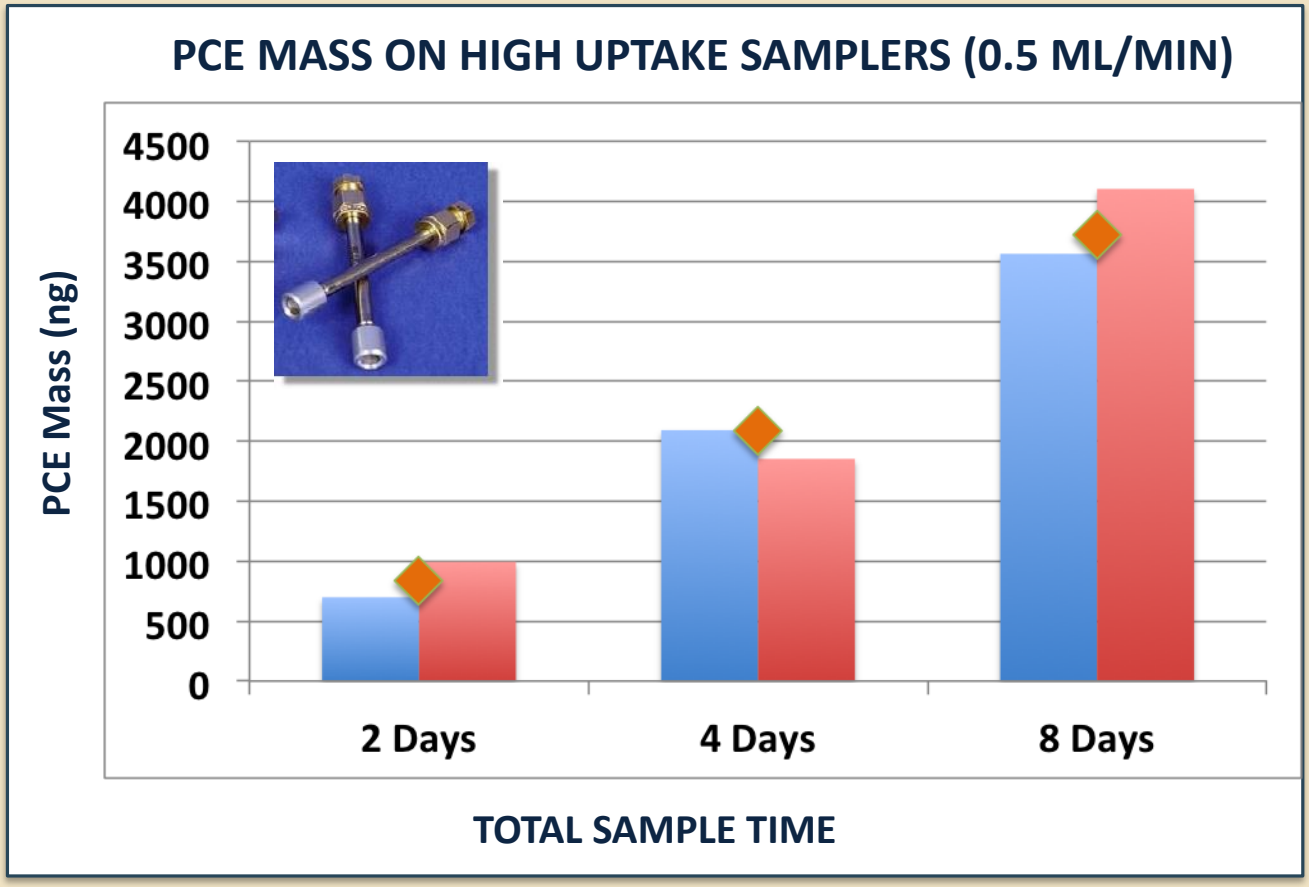
It's not easy to keep PCE in water!

EXPERIMENT 3: HIGH UPTAKE SAMPLER



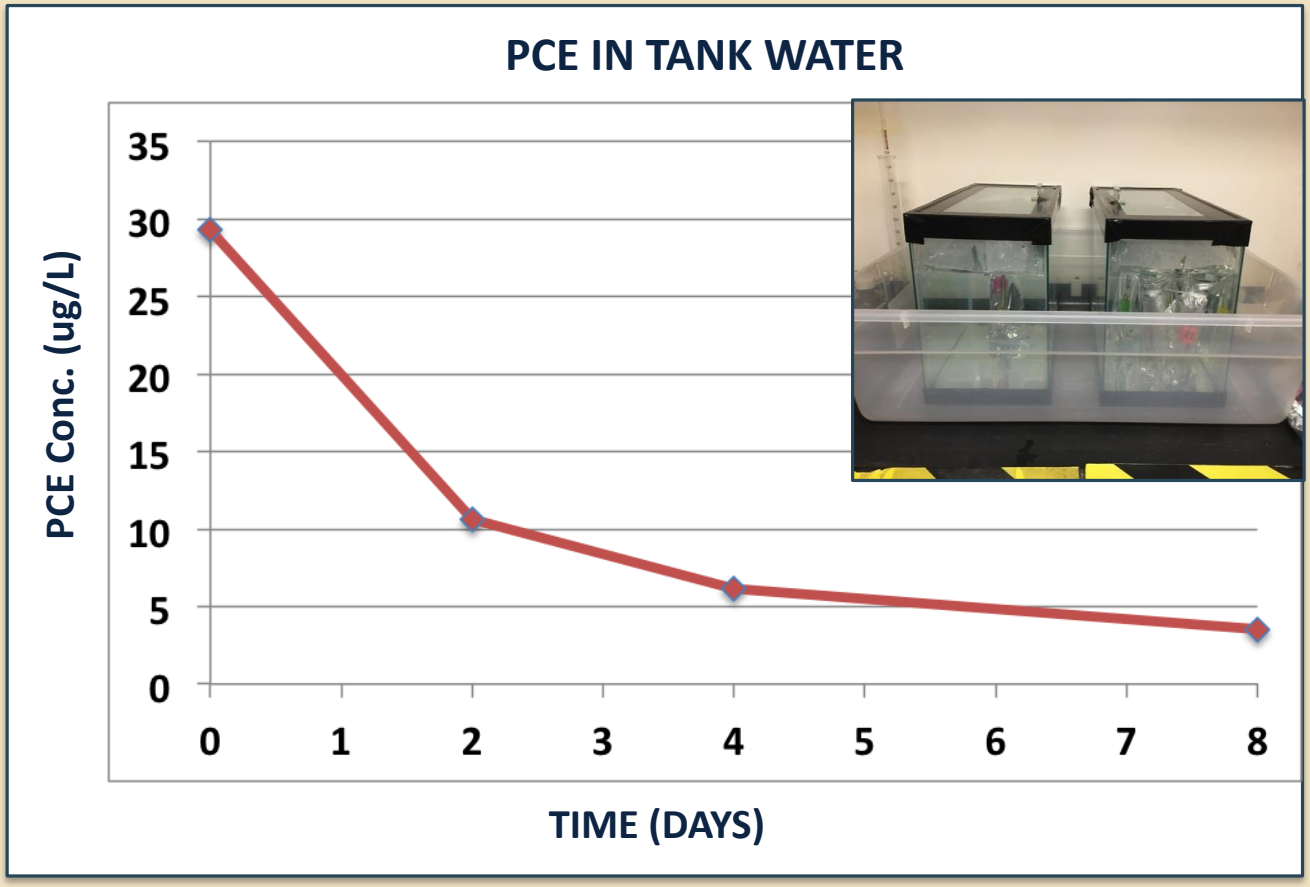
KEY POINT: ***Good agreement between dups. >> Sampler results are reproducible.***

LABORATORY VALIDATION: EXPERIMENT 3



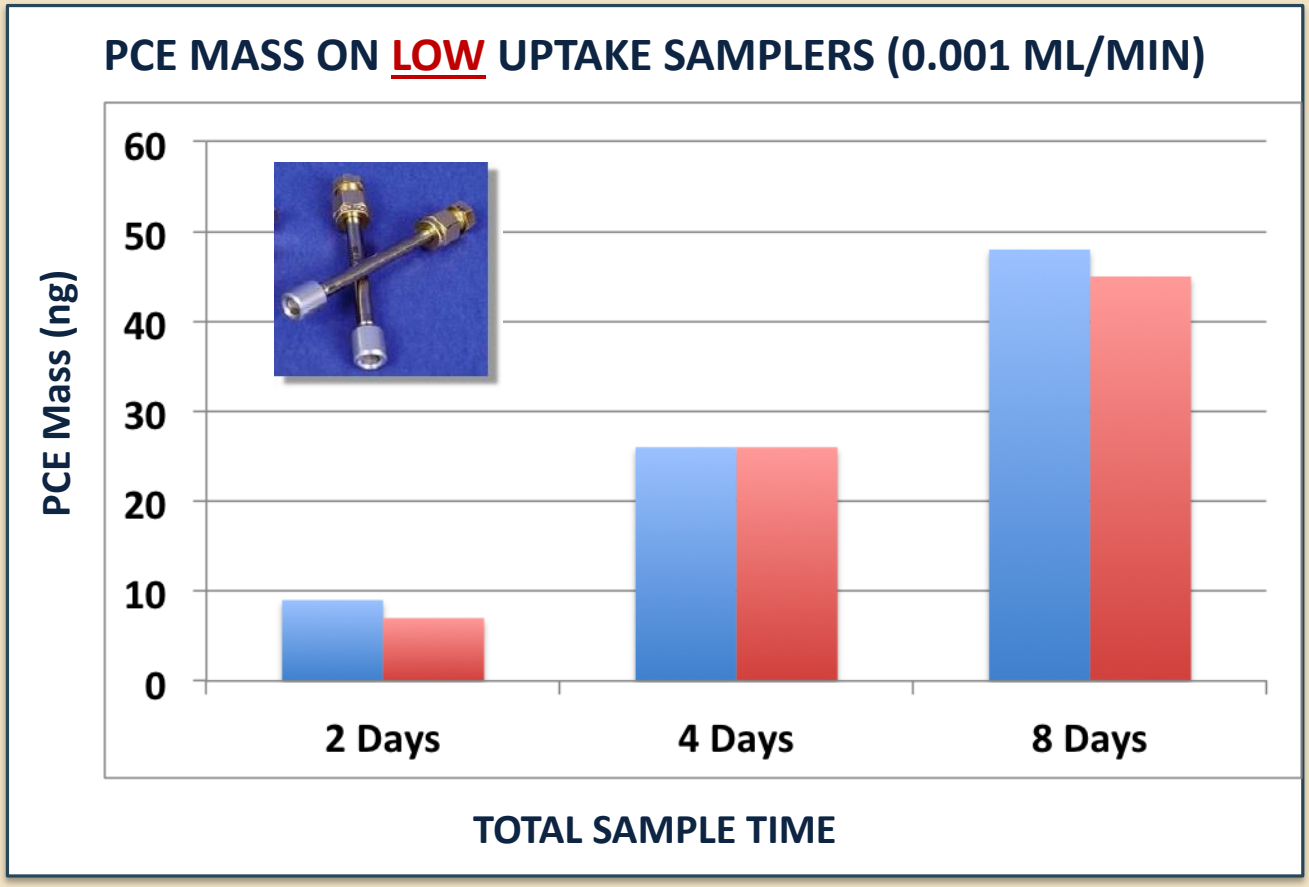
KEY POINT: *Can accurately predict PCE on sorbent tube based on measured PCE in water (after model calibration).*

EXPERIMENT 4: LOW UPTAKE SAMPLER



PCE concentration in water is similar to Experiment 3

EXPERIMENT 4: LOW UPTAKE SAMPLER

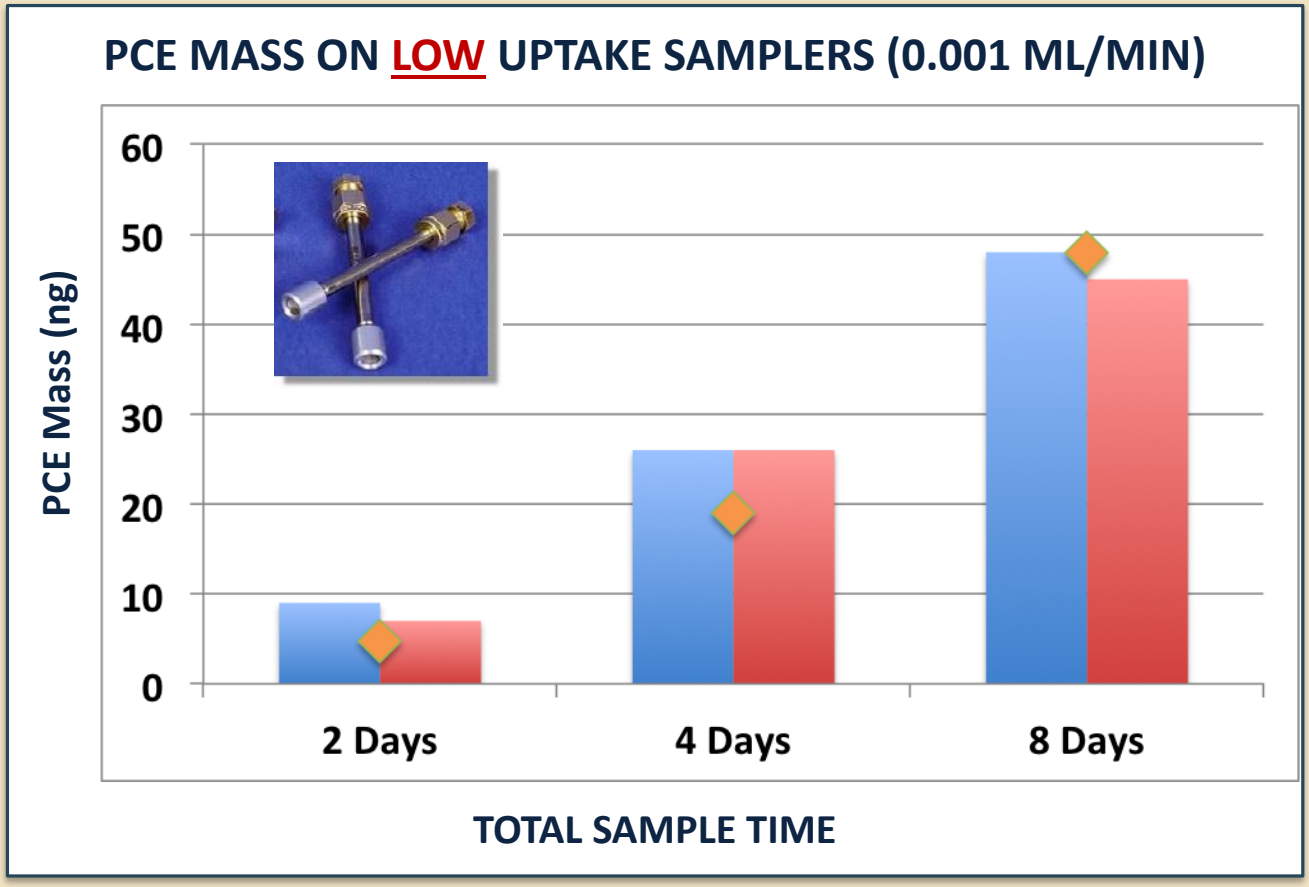


KEY POINT:

GREAT agreement between dups

Much lower PCE mass on samplers (due to lower uptake rate)

LABORATORY VALIDATION: EXPERIMENT 4



KEY POINT:

Can accurately predict PCE on sorbent tube based on measured PCE in water.
>> Used model calibration from Experiment #3!!

FIELD VALIDATION

DOES THE SAMPLER WORK? (IN THE FIELD)

FIELD VALIDATION

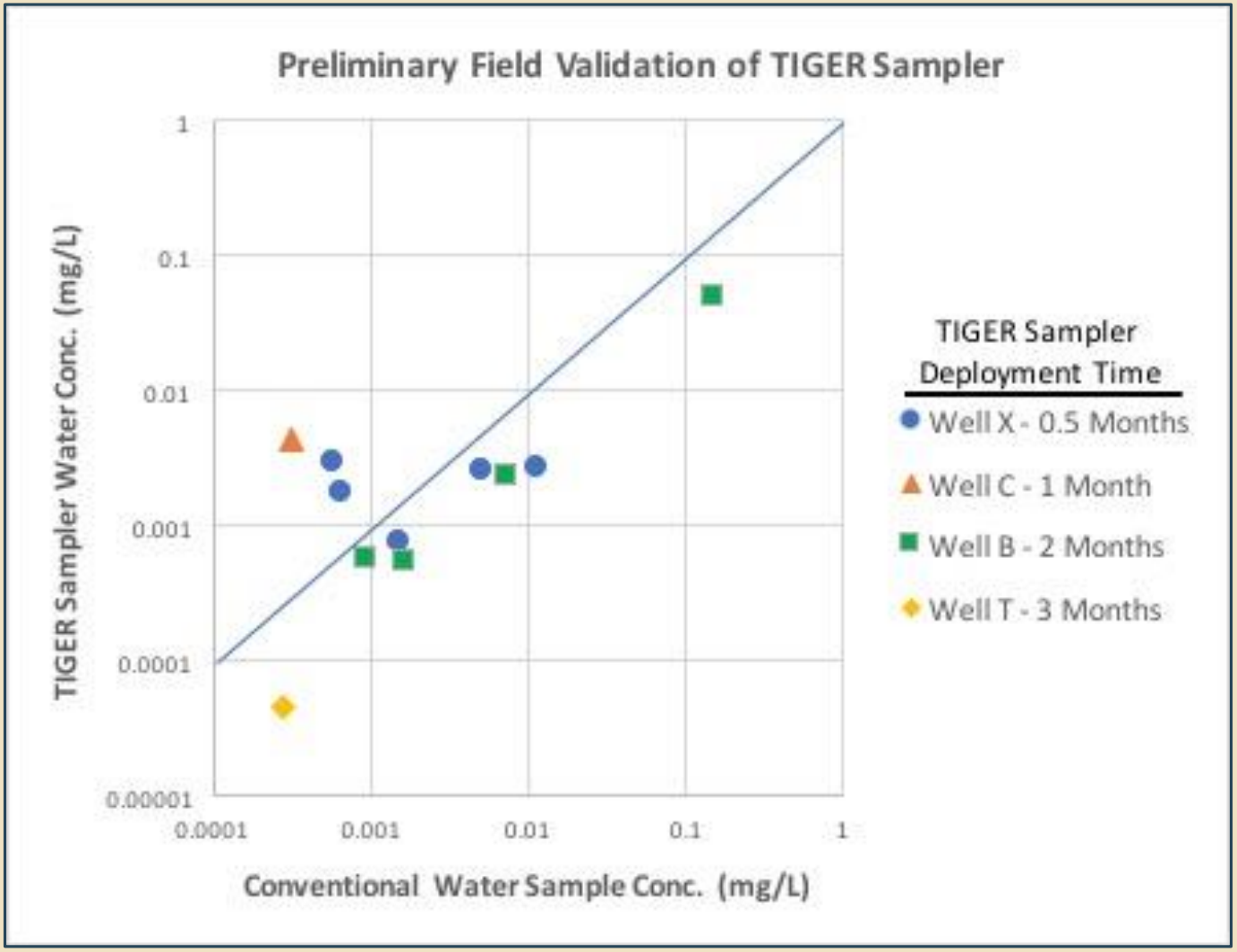
Validation Program

1) Four wells – chlorinated VOCs

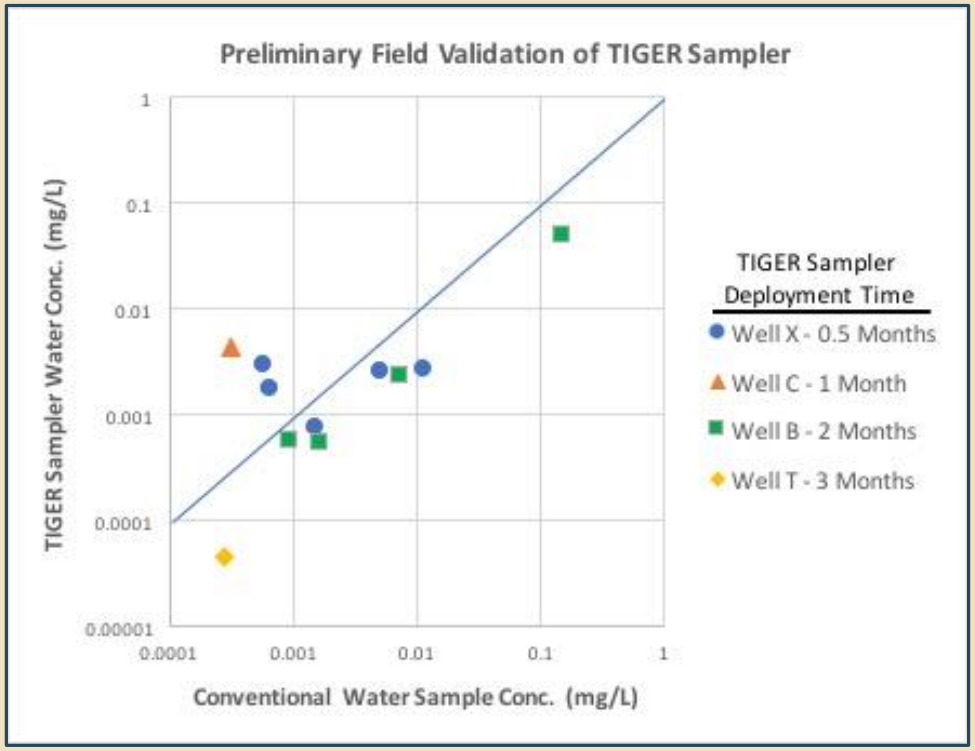
2) Deploy samplers (duplicate pairs)
   - 2 weeks, 1 month
   - 2 months, 3 months

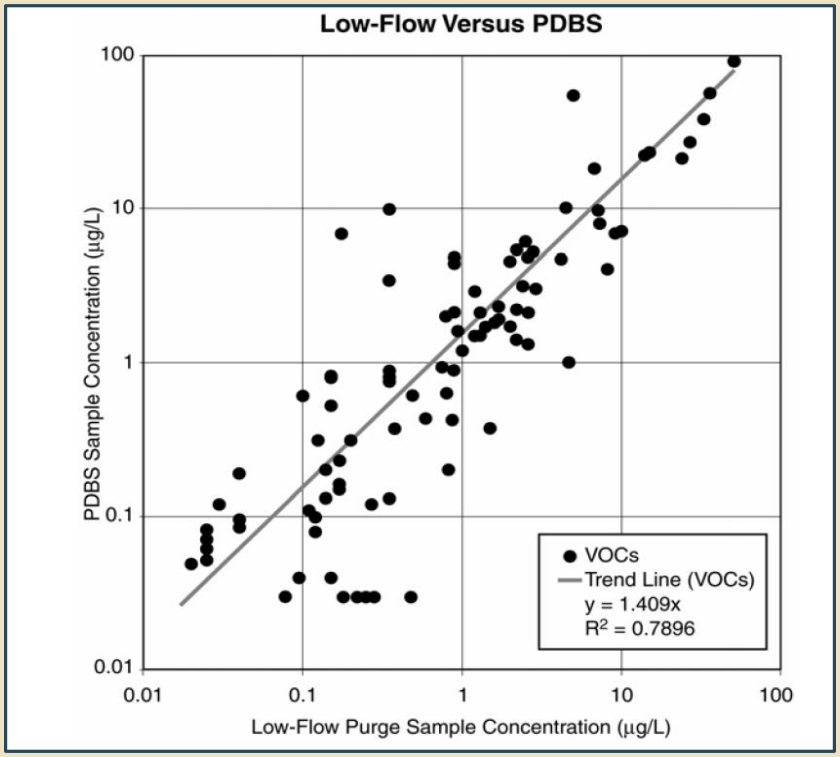
3) Compare sampler results to conventional low-flow purge samplers

FIELD VALIDATION



FIELD VALIDATION





KEY POINT:

Correlation between TIGER and low-flow sample is similar to that observed between any paired purge and no-purge sample methods.

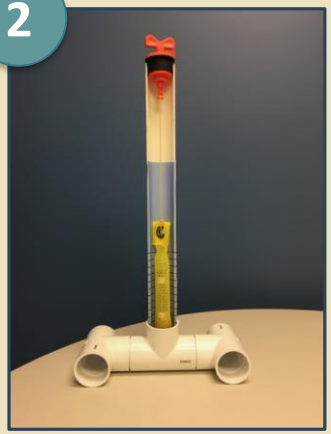
TIGER SAMPLER: HOW TO USE

Collecting a Sample

1) Remove from package and place in well screen interval
2) Wait 3 months
3) Remove from well and place kinetic sampler in package
4) Send to lab (in a box, no ice)

1

2



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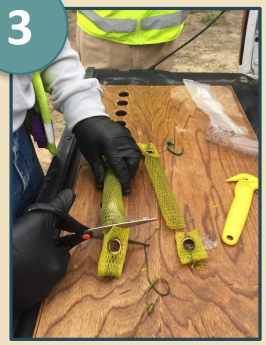


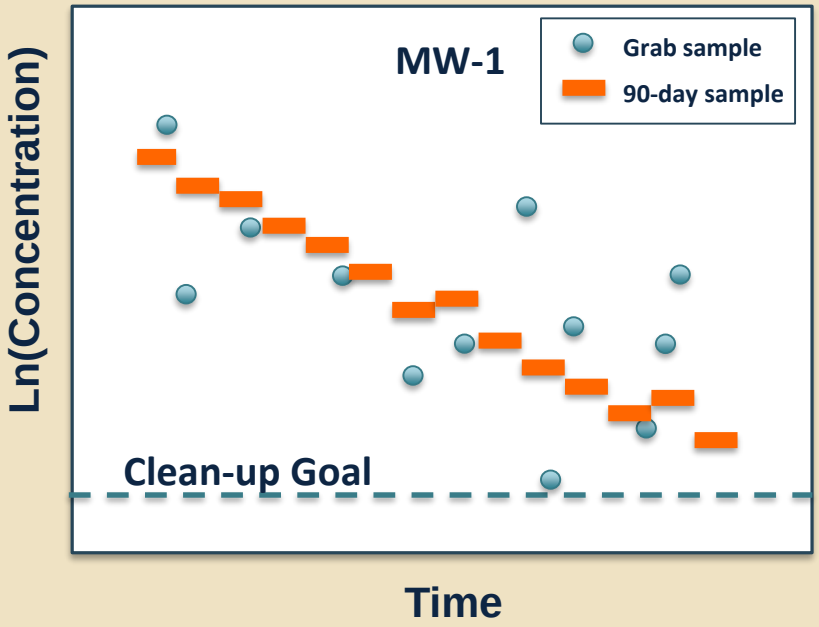
4

Advantages: *- Reduced sampler deployment time*
- No purge waste
- Ship at ambient temperature (no cooler, no ice)

TIGER SAMPLER: WHY?

Advantage of time-integrated data

- Less data variability
  - Less confusion
  - More accurate clean-up time estimates

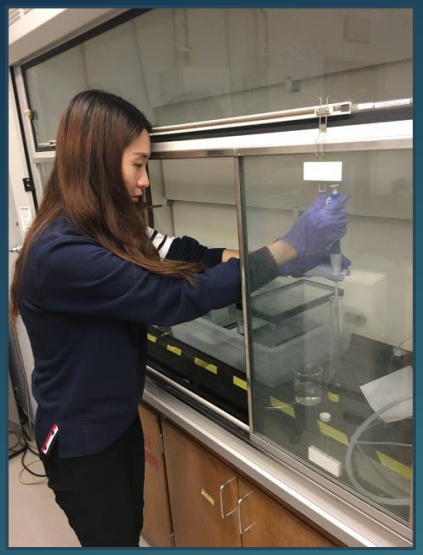


TIME INTEGRATED SAMPLER FOR GW?

Development Process

PATENT APPLICATION	✓
LAB VALIDATION	✓
FIELD VALIDATION	On-going
COMMERCIALIZATION	2017

ACKNOWLEDGEMENTS



Laboratory Validation Study:
Ciara Simmons-Pino, Rice University
Caroline Li, Rice University
Rob Griffin, Rice University
Ben Medina, GSI Environmental
John Connor, GSI Environmental

Field Validation Study:
James Anderson, Rebekah Westrup, Mark Lach, Adriana Handszer, Roberto Sosa (All w/ Cardeno)

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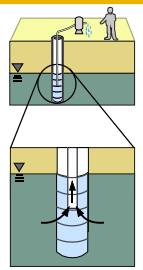

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