What Is the Influence of Equilibration Time on Soil Gas Results?

Angela Haar, Ph.D. and Steve Jones, Ph.D.

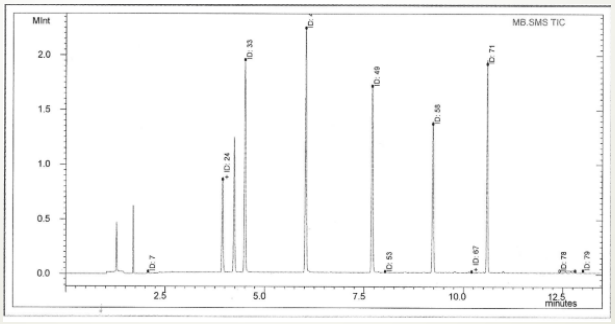
Jones Environmental, Inc.
Santa Fe Springs, CA

Soil Gas Sampling

- Follow Latest DTSC Soil-Gas Advisory (2015)
- Certified Magnehelic
  - 0.01- >100 inH_2O
- High-Precision Pump
  - 200 mL/min or 1000-5000 mL/min
- Shut-in Test/Tracer
- Collection in Gastight Glass Syringes
  - 100 mL for commercial RLs (0.020 µg/L)
  - 250 mL for commercial RLs (0.008 µg/L)

Soil Gas Analysis

- EPA Method 8260-VOCs, Oxygenates, and Gasoline Range Organics
  - Purge & Trap Concentrator
  - Gas Chromatography – Mass Spectrometry (Ion Trap)



Factors Influencing Soil Gas Results*

- "Natural" Factors
  - Lithology
  - Moisture/humidity
  - Temperature
  - Barometric Pressure
- "Man-made" Factors
  - Well construction
  - Well conditioning (purging, equilibration time)

**aside from the contamination itself*

Factors Influencing Soil Gas Results*

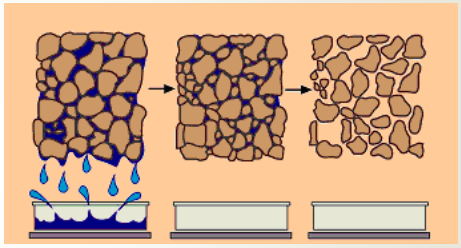
- "Natural" Factors
  - o **Lithology**
  - o Moisture/humidity
  - o Temperature
  - o Barometric Pressure
- "Man-made" Factors
  - o Well construction
  - o Well conditioning (purging, equilibration time)

**aside from the contamination itself*

JONES

Factors Influencing Soil Gas Results*

- "Natural" Factors
  - o Lithology
  - o **Moisture/humidity**
  - o Temperature
  - o Barometric Pressure
- "Man-made" Factors
  - o Well construction
  - o Well conditioning (purging, equilibration time)



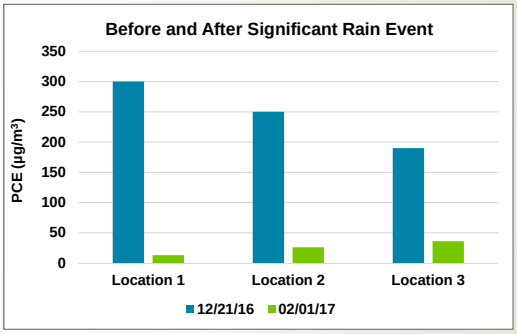
http://www.tankonyvtar.hu/hu/tartalom/tamop425/0032_talajtan/ch07s02.html

**aside from the contamination itself*

JONES

Factors Influencing Soil Gas Results*

- "Natural" Factors
  - o Lithology
  - o **Moisture/humidity**
  - o Temperature
  - o Barometric Pressure
- "Man-made" Factors
  - o Well construction
  - o Well conditioning (purging, equilibration time)

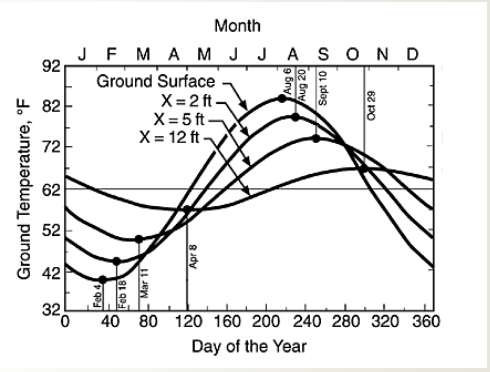


**aside from the contamination itself*

JONES

Factors Influencing Soil Gas Results*

- "Natural" Factors
  - o Lithology
  - o Moisture/humidity
  - o **Temperature**
  - o Barometric Pressure
- "Man-made" Factors
  - o Well construction
  - o Well conditioning (purging, equilibration time)



http://www.builditsolar.com/Projects/Cooling/EarthTemperatures.htm

**aside from the contamination itself*

JONES

Factors Influencing Soil Gas Results*

- "Natural" Factors
  - Lithology
  - Moisture/humidity
  - Temperature
  - **Barometric Pressure**
- "Man-made" Factors
  - Well construction
  - Well conditioning (purging, equilibration time)

- Los Angeles
  - Record high of 30.59 inHg
  - Record low of 29.07 inHg
- San Diego
  - Record high of 30.53 inHg
  - Record low of 29.15 inHg

www.wunderground.com/resources/pressure_records.asp

*aside from the contamination itself

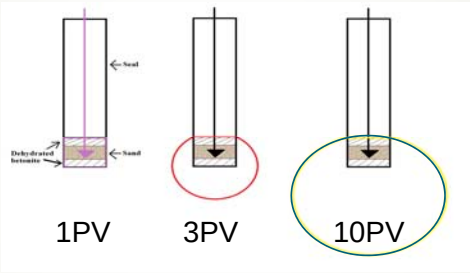
Factors Influencing Soil Gas Results*

- "Natural" Factors
  - Lithology
  - Moisture/humidity
  - Temperature
  - Barometric Pressure
- **"Man-made" Factors**
  - **Well construction**
  - **Well conditioning (purging, equilibration time)**

*aside from the contamination itself

Preparation: Soil Gas Well Purging

- Removal of stagnant air prior to sample collection

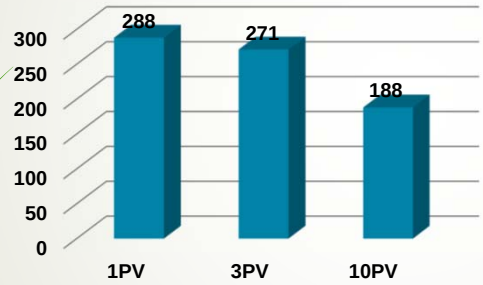


- Prior to 2015 purge volume determined by purge test
  - 2012 and before: 1PV, 3PV and 7PV
  - 2012-2015: 1PV, 3PV and 10PV
- After 2015 converted to a 3 PV default

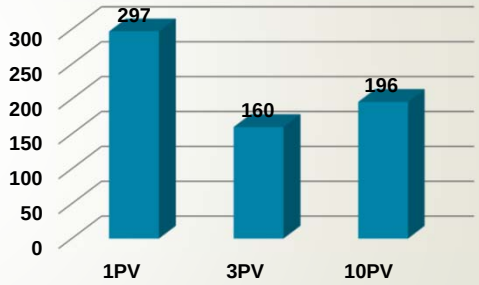
Recap: Purge Volume Tests

(Jones & Pulleva, AEHS 2015)

2012-2015



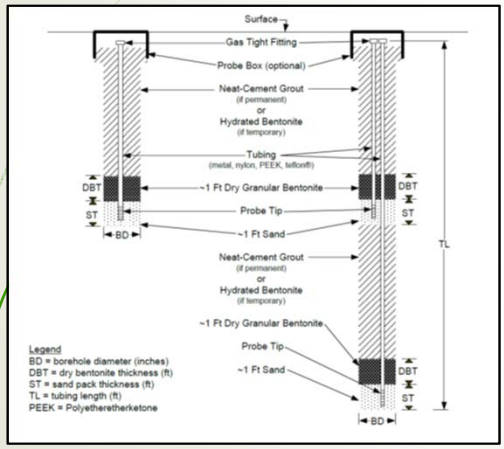
All Sites (747 total)



3PV Default Sites Removed (653 total)

Soil Gas Well Construction

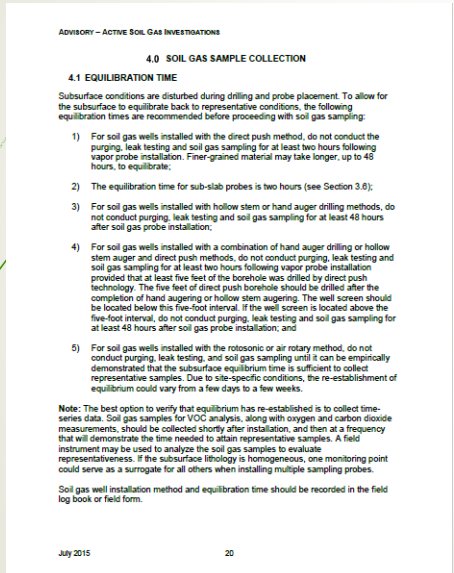
Construction



Installation

- Direct Push
- Hollow Stem Auger
- Hand Auger
- Air Rotary/Rotosonic

Equilibration Time



ADVISORY – ACTIVE SOIL GAS INVESTIGATIONS

4.0 SOIL GAS SAMPLE COLLECTION

4.1 EQUILIBRATION TIME

Subsurface conditions are disturbed during drilling and probe placement. To allow for the subsurface to equilibrate back to representative conditions, the following equilibration times are recommended before proceeding with soil gas sampling:

1) For soil gas wells installed with the direct push method, do not conduct the purging, leak testing and soil gas sampling for at least two hours following vapor probe installation. Finer-grained material may take longer, up to 48 hours, to equilibrate;

2) The equilibration time for sub-slab probes is two hours (see Section 3.6);

3) For soil gas wells installed with hollow stem or hand auger drilling methods, do not conduct purging, leak testing and soil gas sampling for at least 48 hours after soil gas probe installation;

4) For soil gas wells installed with a combination of hand auger drilling or hollow stem auger and direct push methods, do not conduct purging, leak testing and soil gas sampling for at least two hours following vapor probe installation provided that at least five feet of the borehole was drilled by direct push technology. The five feet of direct push borehole should be drilled after the completion of hand augering or hollow stem augering. The well screen should be located below this five-foot interval. If the well screen is located above the five-foot interval, do not conduct purging, leak testing and soil gas sampling for at least 48 hours after soil gas probe installation; and

5) For soil gas wells installed with the rotosonic or air rotary method, do not conduct purging, leak testing, and soil gas sampling until it can be empirically demonstrated that the subsurface equilibrium time is sufficient to collect representative samples. Due to site-specific conditions, the re-establishment of equilibrium could vary from a few days to a few weeks.

Note: The best option to verify that equilibrium has re-established is to collect time-series data. Soil gas samples for VOC analysis, along with oxygen and carbon dioxide measurements, should be collected shortly after installation, and then at a frequency that will demonstrate the time needed to attain representative samples. A field instrument may be used to analyze the soil gas samples to evaluate representativeness. If the subsurface lithology is homogeneous, one monitoring point could serve as a surrogate for all others when installing multiple sampling probes.

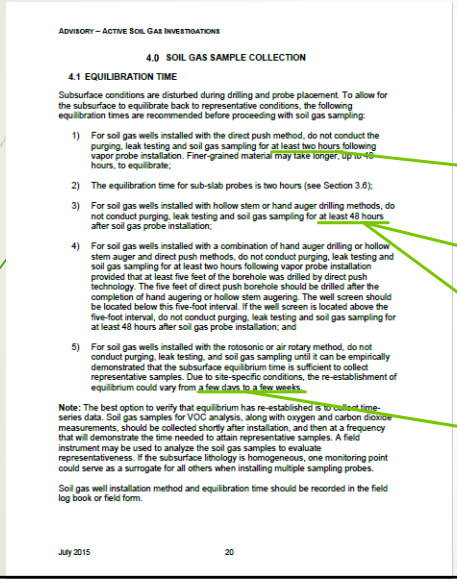
Soil gas well installation method and equilibration time should be recorded in the field log book or field form.

July 2015 20

Installation

- Direct Push
- Hollow Stem Auger
- Hand Auger
- Air Rotary/Rotosonic

Equilibration Time



ADVISORY – ACTIVE SOIL GAS INVESTIGATIONS

4.0 SOIL GAS SAMPLE COLLECTION

4.1 EQUILIBRATION TIME

Subsurface conditions are disturbed during drilling and probe placement. To allow for the subsurface to equilibrate back to representative conditions, the following equilibration times are recommended before proceeding with soil gas sampling:

1) For soil gas wells installed with the direct push method, do not conduct the purging, leak testing and soil gas sampling for at least two hours following vapor probe installation. Finer-grained material may take longer, up to 48 hours, to equilibrate;

2) The equilibration time for sub-slab probes is two hours (see Section 3.6);

3) For soil gas wells installed with hollow stem or hand auger drilling methods, do not conduct purging, leak testing and soil gas sampling for at least 48 hours after soil gas probe installation;

4) For soil gas wells installed with a combination of hand auger drilling or hollow stem auger and direct push methods, do not conduct purging, leak testing and soil gas sampling for at least two hours following vapor probe installation provided that at least five feet of the borehole was drilled by direct push technology. The five feet of direct push borehole should be drilled after the completion of hand augering or hollow stem augering. The well screen should be located below this five-foot interval. If the well screen is located above the five-foot interval, do not conduct purging, leak testing and soil gas sampling for at least 48 hours after soil gas probe installation; and

5) For soil gas wells installed with the rotosonic or air rotary method, do not conduct purging, leak testing, and soil gas sampling until it can be empirically demonstrated that the subsurface equilibrium time is sufficient to collect representative samples. Due to site-specific conditions, the re-establishment of equilibrium could vary from a few days to a few weeks.

Note: The best option to verify that equilibrium has re-established is to collect time-series data. Soil gas samples for VOC analysis, along with oxygen and carbon dioxide measurements, should be collected shortly after installation, and then at a frequency that will demonstrate the time needed to attain representative samples. A field instrument may be used to analyze the soil gas samples to evaluate representativeness. If the subsurface lithology is homogeneous, one monitoring point could serve as a surrogate for all others when installing multiple sampling probes.

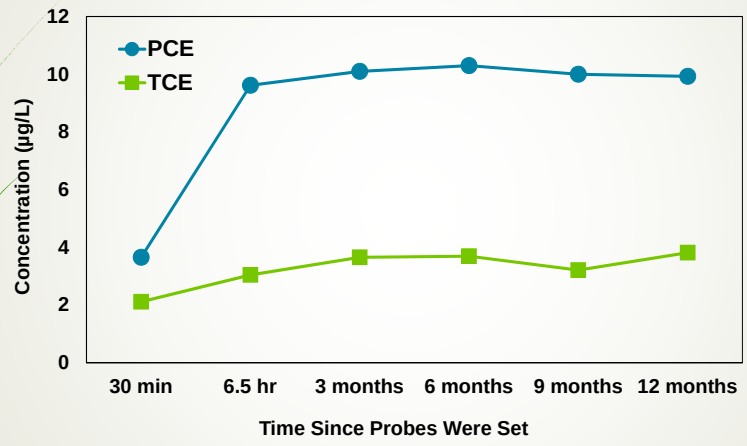
Soil gas well installation method and equilibration time should be recorded in the field log book or field form.

July 2015 20

Installation

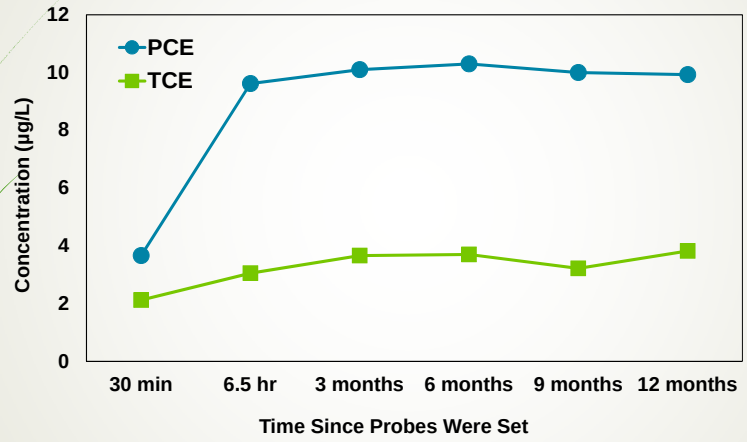
- Direct Push
  - *2hr*
- Hollow Stem Auger
  - *48hr*
- Hand Auger
  - *48hr*
- Air Rotary/Rotosonic
  - *Days to Weeks*

How Long Until Equilibration?



<u>Summer 2009</u>
Study on influence of barometric pressure

How Long Until Equilibration?



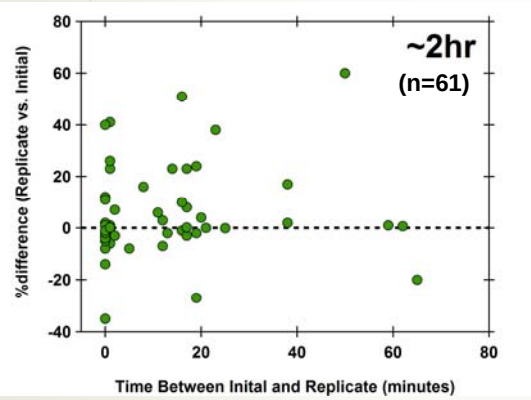
Summer 2009
Study on influence of barometric pressure

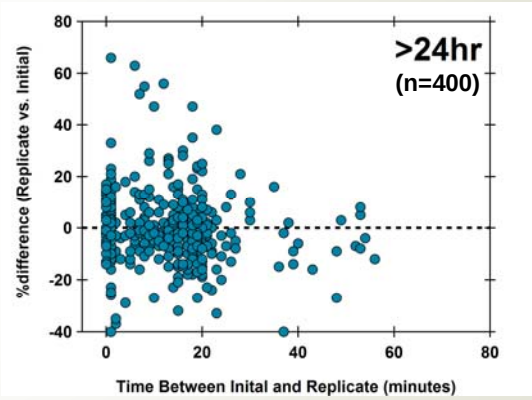
- 1 of 30 probes
- 1 of 18 sites

} Results consistent for all probes/sites

Replicate Samples: ~2hr vs. >24hr

Perchloroethene

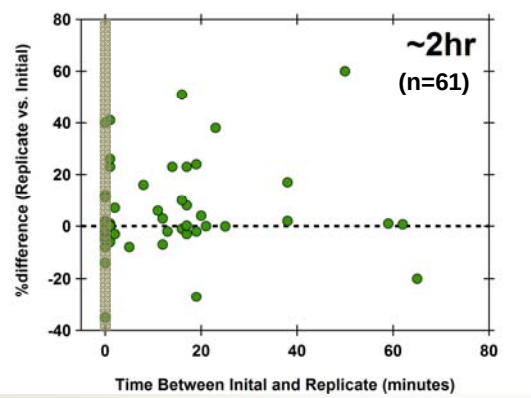


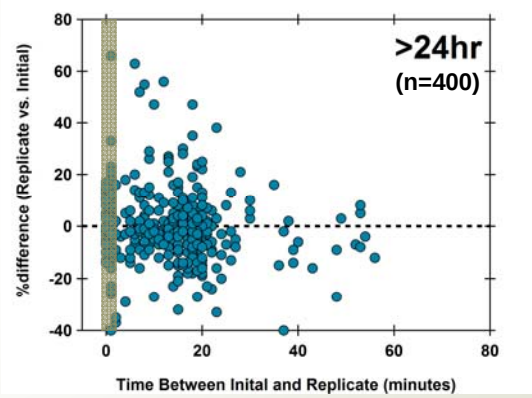


2015 & 2016, All Sites

Replicate Samples: ~2hr vs. >24hr

Perchloroethene

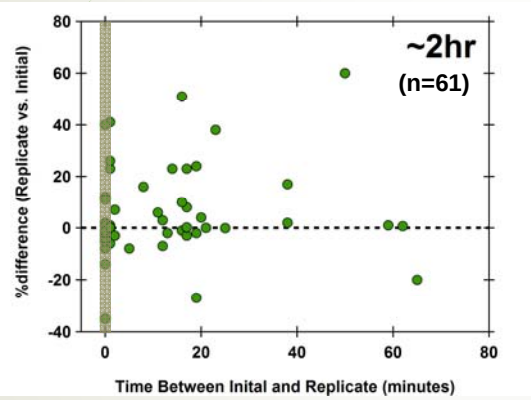


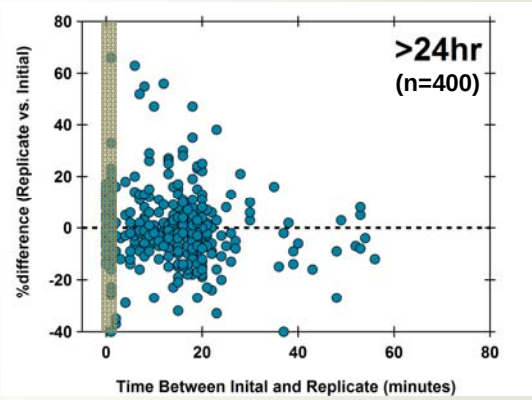


JONES

Replicate Samples: ~2hr vs. >24hr

Perchloroethene





↑69% ↓31%

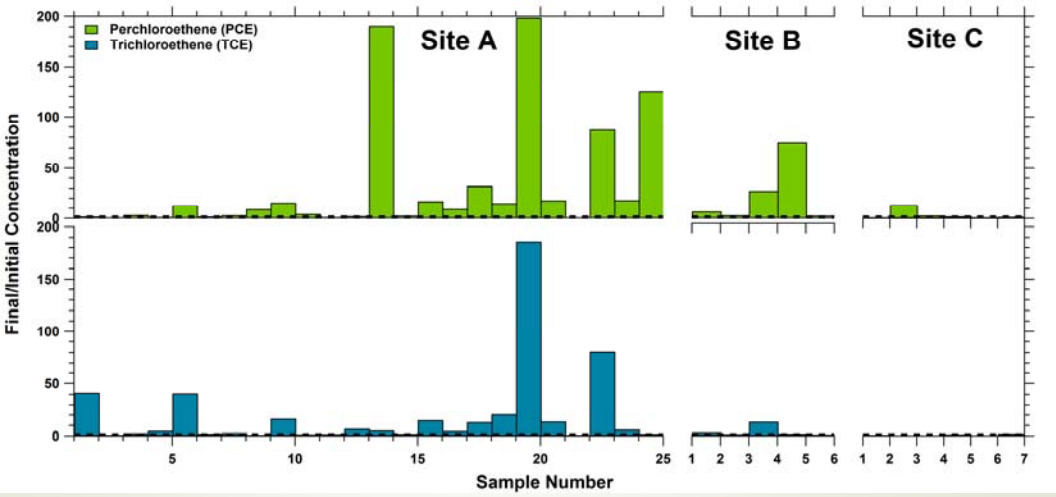
↑50% ↓50%

JONES

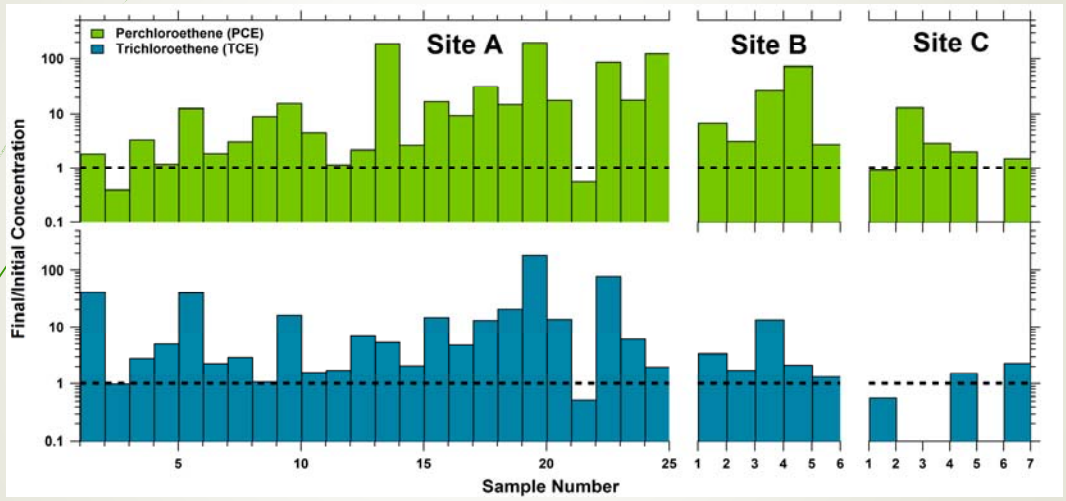
Repeat Analysis: 3 Examples

- Conducted on-site soil gas analysis both immediately following the 2hr equilibration period and on a later date:
  - Site A: ~2 hours and ~6 months (October vs. April)
  - Site B: ~2 hours and ~4 months (February vs. June)
  - Site C: ~2 hours and ~2 days (August)
- Saw significantly different results between the two different days with a tendency toward higher values on the later date.

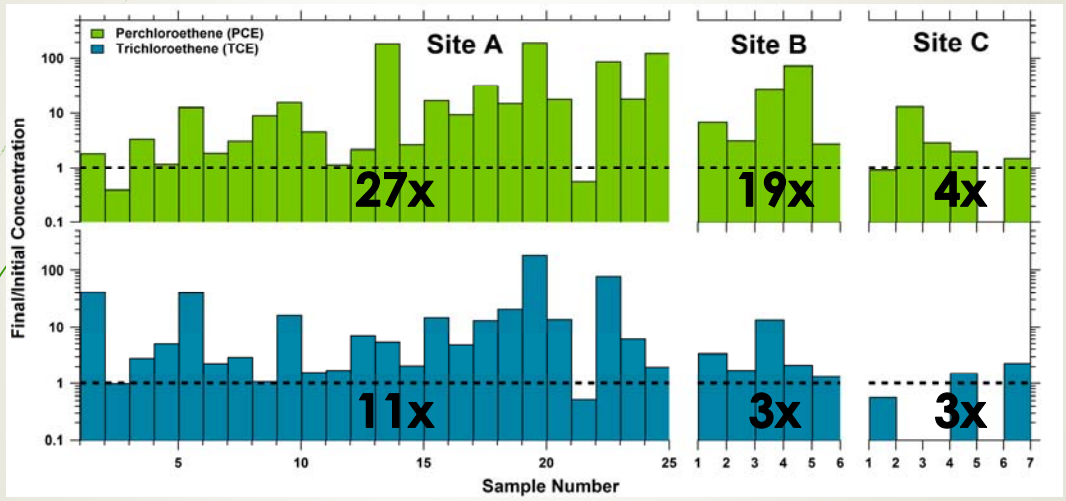
Equilibration Time Comparison



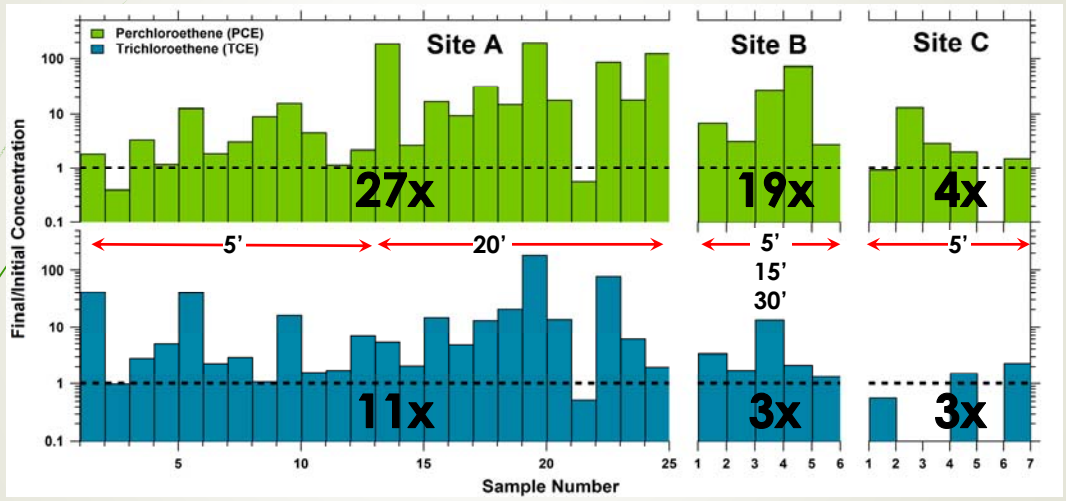
Equilibration Time Comparison



Equilibration Time Comparison

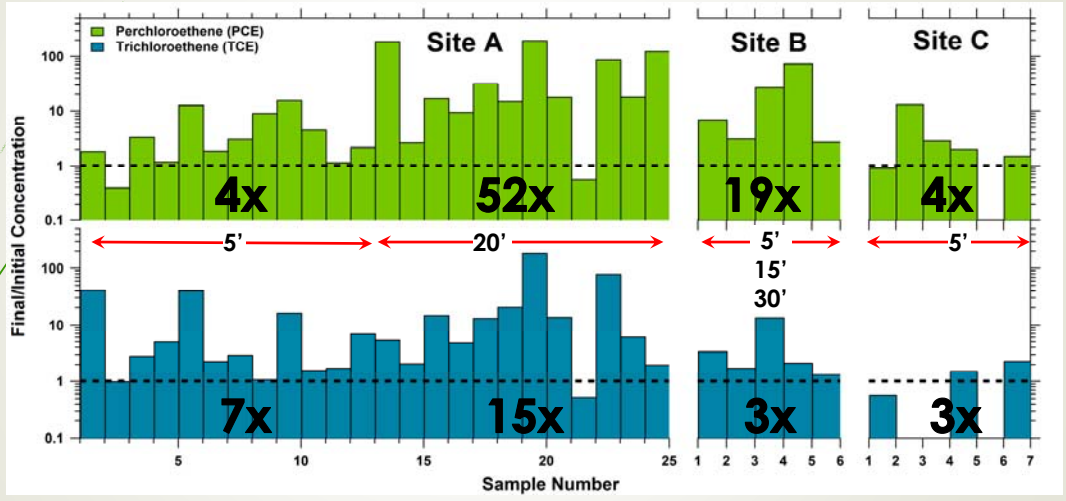


Equilibration Time Comparison



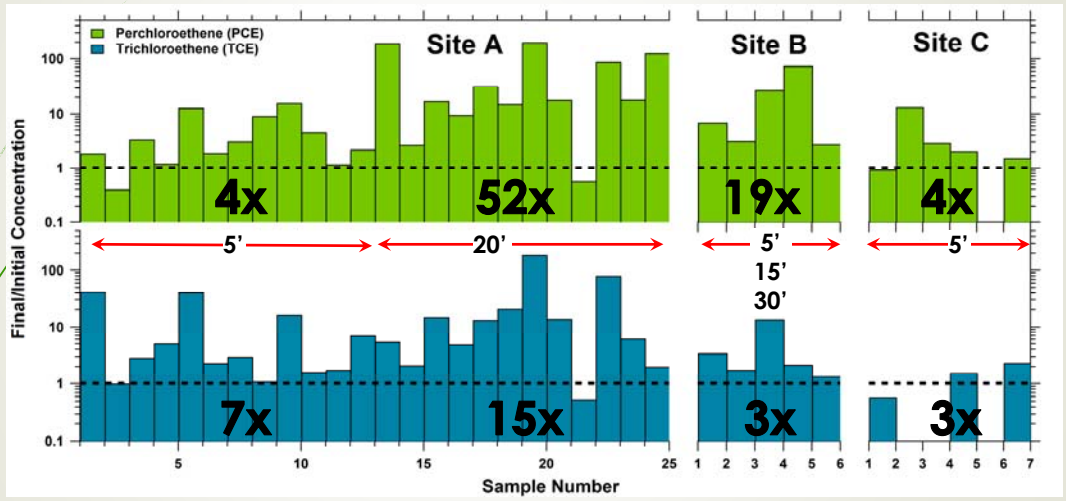
JONES

Equilibration Time Comparison



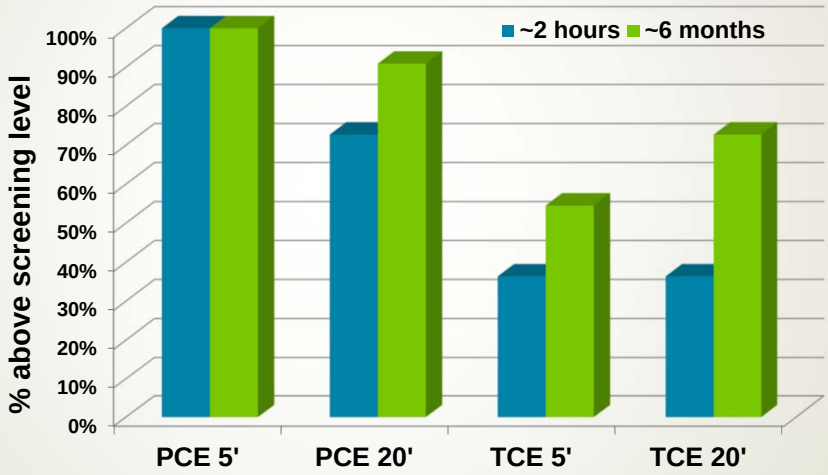
JONES

Equilibration Time Comparison



Similar results not observed for sub slab samples

Equilibration Time Comparison



Site A (25 samples)

Summary and Outlook

- Barometric pressure does not influence soil gas data significantly
- One purge volume (or less) should be used as a default instead of three purge volumes
- The presence of water in the soil influences soil gas results
- Equilibration times should be greater than two hours
  - No evidence for significant differences in soil gas data after 48 hours
- Sub-slab samples are unaffected by equilibration times
- Deeper samples (>5 feet) need longer equilibration times and are more affected by drilling/probe installation operations

JONES

Thank You!

The Jones Environmental Team
Carolyn Carroll
Colby Wakeman
Tania Camacho
Jessica Kyees
Emily Rosa
Emma Pulleva

JONES

Gas Phase Behavior

- **Ideal Gas Law:**

$$PV = nRT$$

- **Dalton's Law of Partial Pressures:**

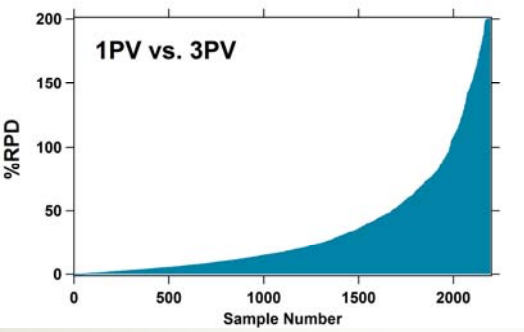
$$P_{total} = P_1 + P_2 + P_3 \ldots\ldots P_n$$

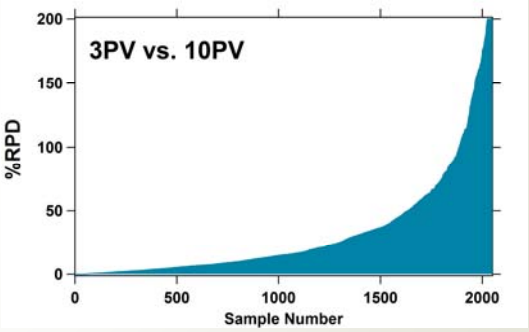
  - For a mixture of non-reacting gases, the total pressure exerted is equal to the sum of the partial pressures of the individual gases.

JONES

Recap: Purge Volume Tests

(Jones & Pulleva, AEHS 2015)



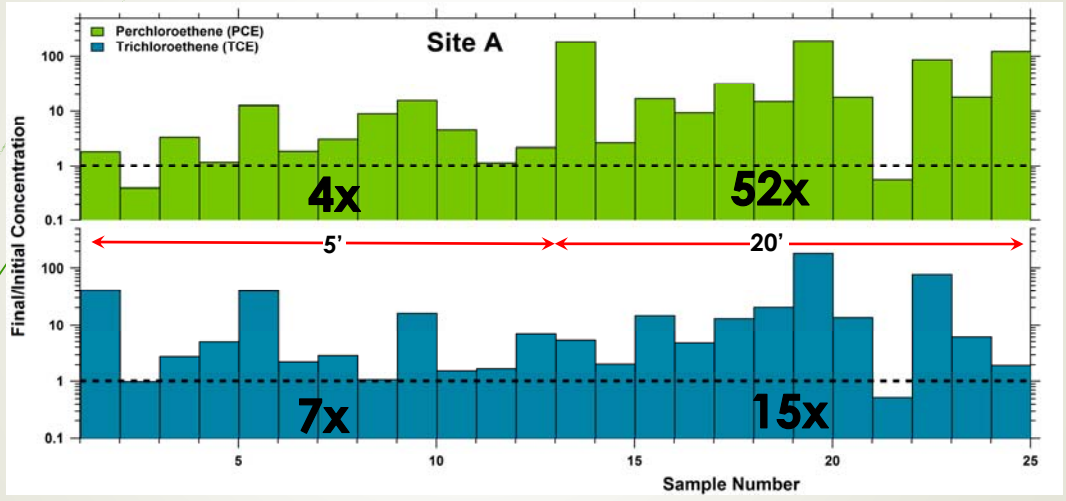


JONES

Method to Determine Equilibration

- Use an O_2/CO_2 meter with pump to continuously monitor O_2 and CO_2 in soil gas
- Once steady state is reached begin sampling the soil gas probe

Equilibration Time Comparison



Similar results not observed for sub slab samples