Arsenic concentration variability in newly constructed drinking water wells in Minnesota, USA

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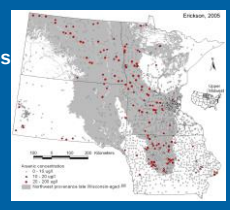

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Arsenic: trace element *and* contaminant

- Naturally present in rock & sediment
- Significant health risks
- EPA MCL & WHO drinking water std: 10 µg/L
  - EPA MCL Goal: 0 µg/L
- Widespread in mid-western groundwater and drinking water
- Minnesota drinking water [As]
  - ≈11% >10 µg/L
  - ≈50% > 2 µg/L

As sampling protocols: uncertainty vs. flexibility

- 2008 New Well Rules in Minnesota
- >43,000 new potable wells tested for As
  - Question: are the As results "good"?
- No specific sample collection protocol
  - Where
  - When
  - Field filtering
- High variability in sampling
  - 180 licensed well drillers
  - 12 certified As-analysis laboratories

Well sampling protocols evaluated

1. Do sampling methods induce bias?
   - Sample collection point (plumbing vs. drill rig)
   - Filtered vs. unfiltered samples
2. Does sampling timing induce bias?
   - Sampling at different time intervals after well construction
- Anecdotal 'knowledge'
  - As goes down over time

Groundwater sample collection

- ~250 newly drilled wells
  - Sampled 3 times between 2014-2016
    - Round 1: Immediately after drilling, 0 months
    - Round 2: 3-6 months after drilling
    - Round 3: 12 months after drilling
- Field parameters collected by MDH:
  pH, temperature, Sp. Conductivity, ORP, Dissolved O_2

Groundwater sample collection

Round 1

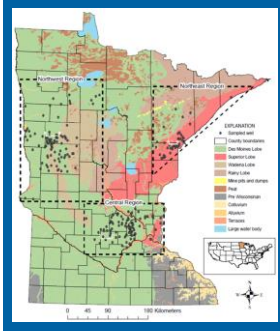
Driller Sample
- From rig or plumbing
- 1 Unfiltered (total As)
- MDH-certified lab

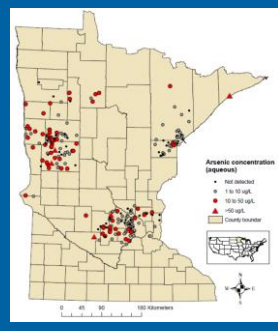
MDH-Sample
- From rig or plumbing
- 1 Unfiltered (total As)
- 1 Filtered (aqueous As)
- MDH Environmental Lab

Rounds 2 and 3

MDH-Sample
- From plumbing
- 1 Unfiltered (total As)
- 1 Filtered (aqueous As)
- MDH Environmental Lab

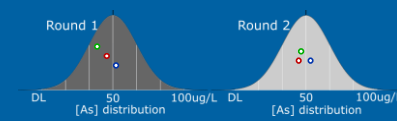
Geologic setting and study wells





Statistical methods

- Summary statistics
- Paired-Prentice Wilcoxon (PPW)
  - Pair-wise comparisons of wells
    - Across time
    - Across sampling methods
  - No distribution assumption
  - Can handle censored data



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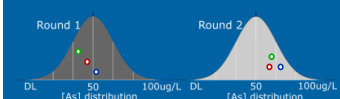
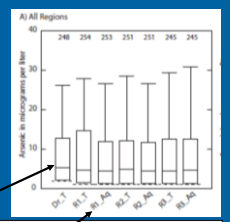
Summary Stats vs. PPW





Paired Prentice-Wilcoxon Test Results		Driller	MDH Collection				
		0 Mo. TAs	0 Mo. TAs	0 Mo. AqAs	3-6 Mo. TAs	3-6 Mo. AqAs	12 Mo. TAs
MDH Collection	0 Mo. TAs	different	---	---	---	---	---
	0 Mo. AqAs	different	different	---	---	---	---
	3-6 Mo. TAs	different	different	not different	---	---	---
	3-6 Mo. AqAs	different	different	not different	different	---	---
	12 Mo. TAs	different	different	not different	not different	not different	---
	12 Mo. AqAs	different	different	not different	not different	not different	not different

Sample collection point

Driller v MDH Common Recensoring	MDH Collection							
	0 Mo. Plumbing		0 Mo. Rig		3-6 Mo. Plumbing		12 Mo. Plumbing	
Driller Collection	TAs	AqAs	TAs	AqAs	TAs	AqAs	TAs	AqAs
0 Mo. Plumbing	Not different	Not different	--	--	Not different	Not different	Not different	Not different
0 Mo. Rig	--	--	Not different	Different	Different	Different	Different	Different

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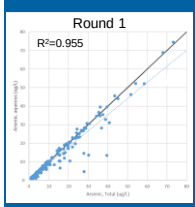
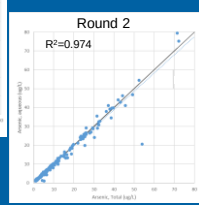
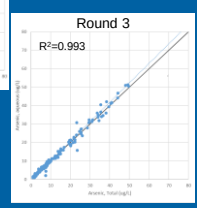
Sample collection timing







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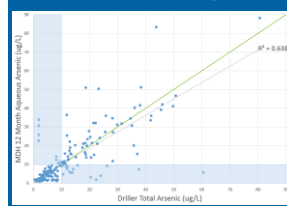
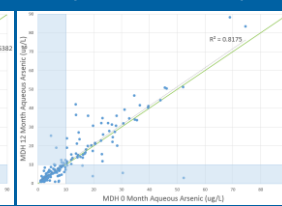
Effect of Filtering Initial Sample

Driller total vs 12 month aqueous



MDH aqueous vs 12 month aqueous



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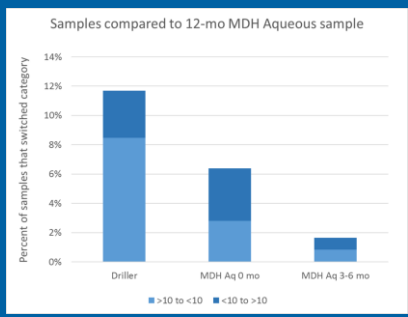
Filtration – MCL category changes



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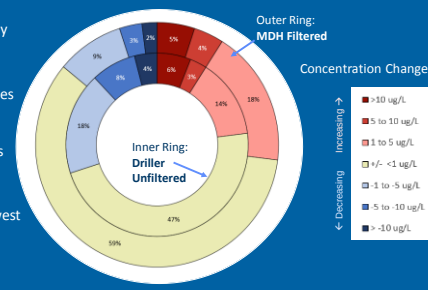
Effect of Filtering Initial Sample: variability between 0-12 months

- Arsenic as likely to increase as decrease
- Filtering reduces variability between 0 and 12 months
- Largest percentages occur with lowest amount of change



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New well variability major findings

- Distribution statistics not adequate to discern point-wise differences
- Some sampling protocols reduce variability in measured arsenic concentration over time
  - Collection from plumbing
  - Filtration of samples
  - Later collection of samples
- [As] can increase with time

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Questions?

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