Regional Assessment of Arsenic in Domestic Drinking Water

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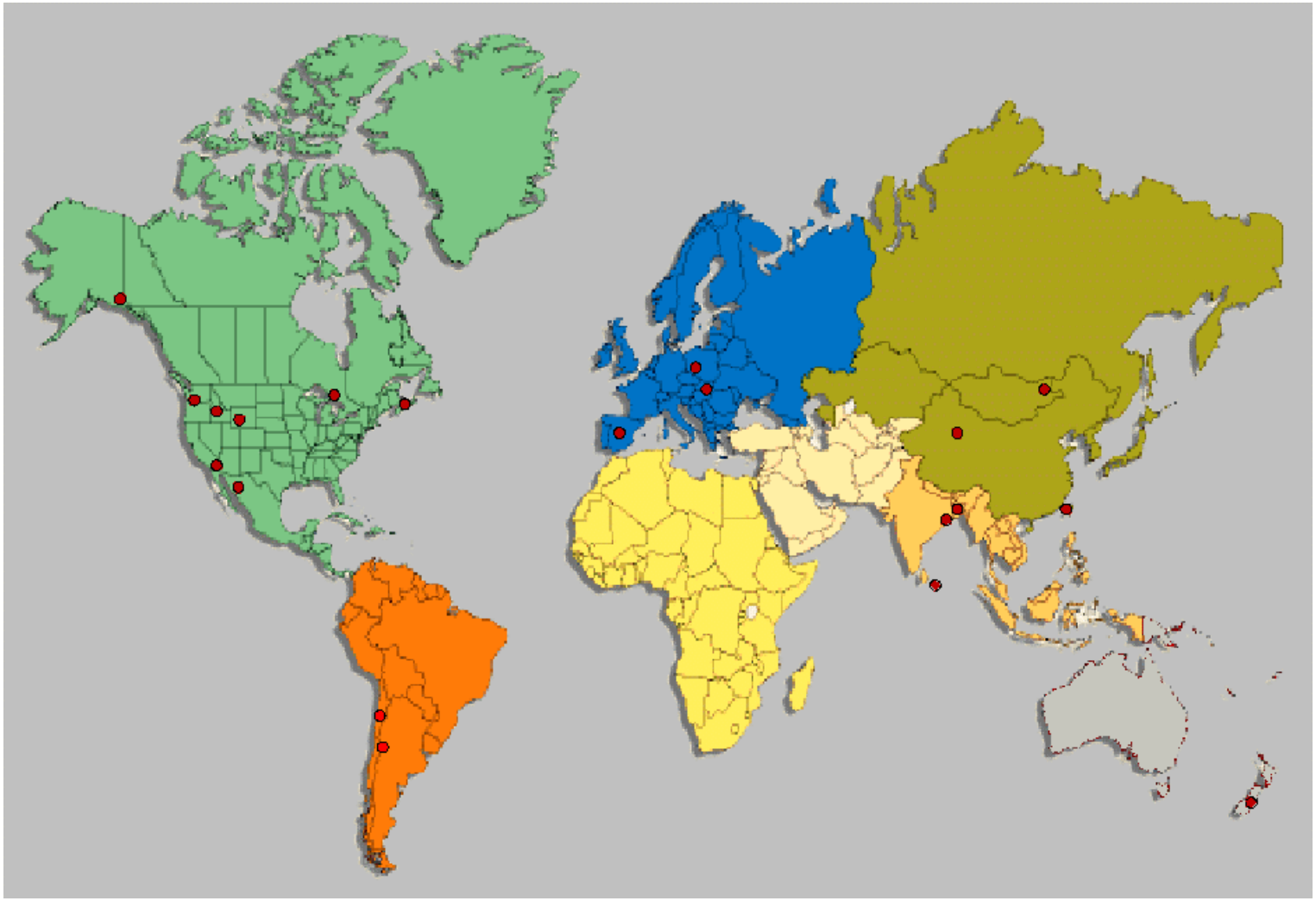
The Arsenic Crisis

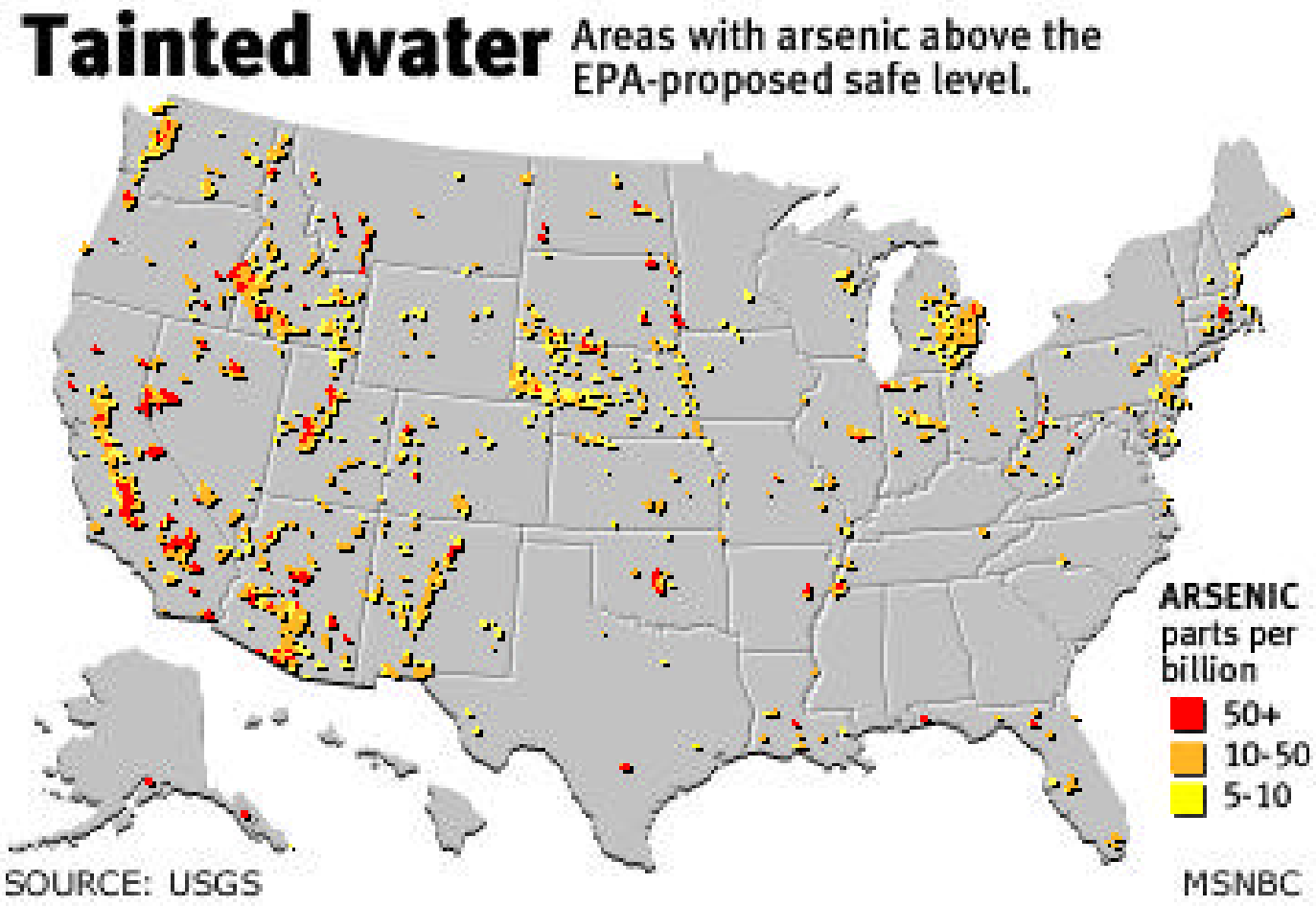
- Naturally occurring element in the earth's crust
- Known carcinogen
- Anthropogenic and Natural source contamination into groundwater
- Affects hundreds of millions of people worldwide particularly in Asia
- Huge economic implications

Worldwide Arsenic Poisoning



Source: Texas A&M University

Arsenic Occurrence in the USA



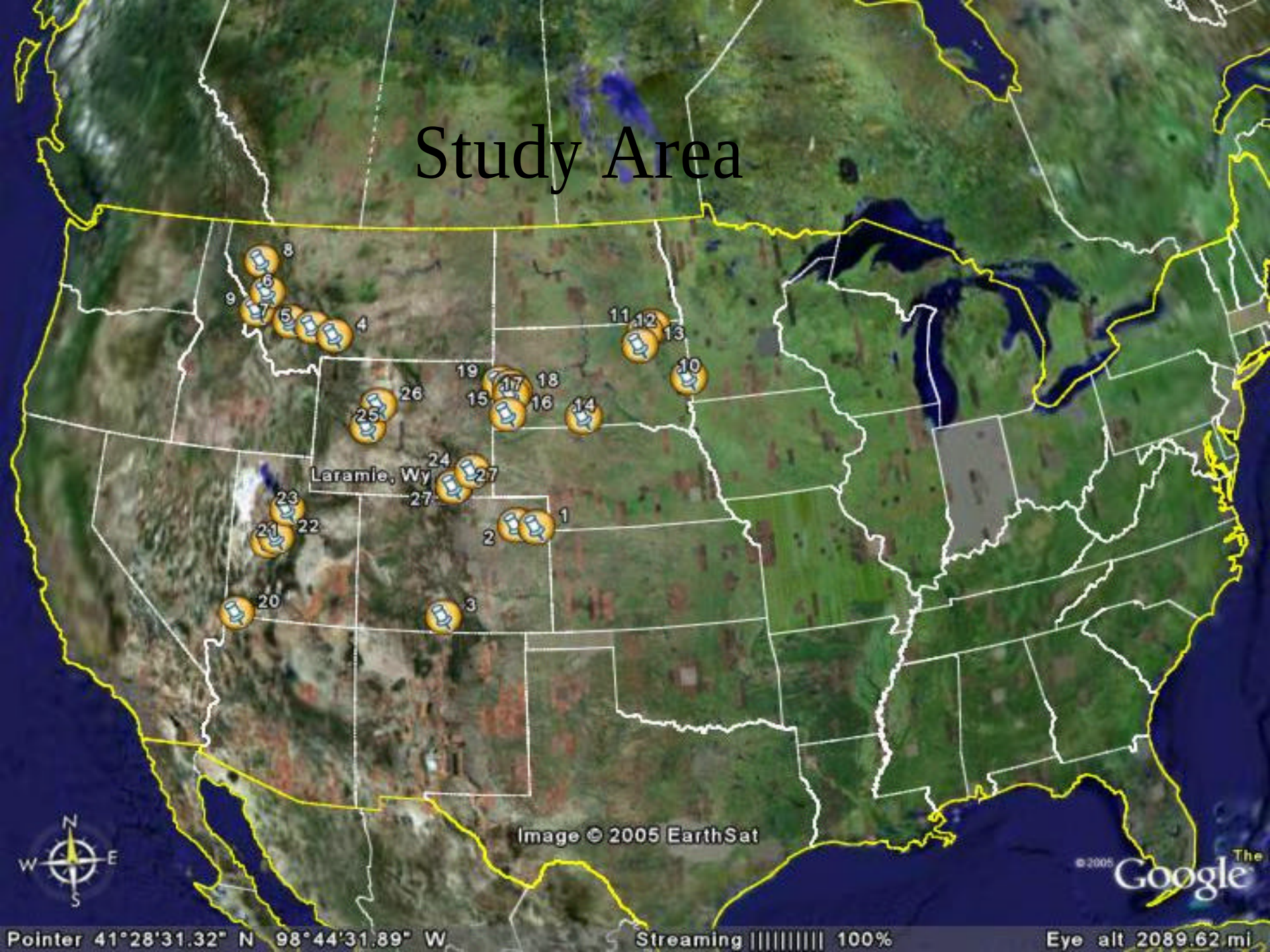
Project Outline

- Locate domestic use wells within EPA Region 8 (WYO, MT, CO, SD, UT)
- Collect groundwater samples from domestic small community or private wells
- React samples that exceed the 10 ug/L EPA imposed limit with ARTI 64® particles to remove arsenic

Target Objectives

- Develop a framework of Network Partners
- Create an outreach and educational program to distribute research results to each of the Network Partners
- Provide information about effective removal techniques for small communities and private well owners

Study Area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Laramie, Wy
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Image © 2005 EarthSat
N
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S
Google
Pointer 41°28'31.32" N 98°44'31.89" W
Streaming |||||||||| 100%
Eye alt 2089.62 mi

Methods

- Create list of Network Partners through the Region 8 CSREES group
- Field Testing
  - Sampled 500 mL from each well
  - Measured pH, EC, ORP, DO, and Temp. on site
- Lab Testing
  - Measured Ca^{2+}, Mg^{2+}, Na^{+}, Fe, Mn, Cr, Si, As, Se, Pb, K
    - Using ICP-MS
  - Measured , F^{-}, Cl^{-}, NO_3^{-}, PO_4^{3-}, SO_4^{2-}
    - Using IC
- Arsenic removal method:
  - 50 mL of sample reacted with 0.5 grams of ARTI 64® particles for 30 minutes then filtered through .45 micron filter paper
  - Analyzed for As with ICP-MS

Colorado Water Chemistry

	As	Si	PO_4^{3-}	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}
Well	**ppb**	ppm	ppm	ppm	ppm	ppm	ppm	ppm
1	**53.1**	49.4	<0.05	9.7	6.7	0.3	40.0	5.4
2	**81.5**	49.6	<0.05	9.2	5.3	0.0	43.0	6.3
3	**50.9**	53.4	<0.05	12.8	6.3	0.2	43.3	7.7
4	**29.0**	17.0	<0.05	88.0	26.6	8.9	120.9	13.6
5	**33.3**	13.4	<0.05	83.4	14.9	4.8	140.7	9.4
6	**11.3**	27.5	<0.05	8.07	33.0	9.9	11.4	8.2
7	8.3	26.9	0.22	6.79	37.0	10.6	10.2	8.2
8	8.0	24.6	<0.05	33.81	64.2	13.5	30.0	10.3
9	**20.5**	52.0	<0.05	7.28	4.9	0.1	36.4	5.1
10	**17.2**	44.0	<0.05	7.46	6.0	0.2	47.9	3.5
11	8.8	47.3	<0.05	5.92	3.8	0.0	35.1	3.6

Montana Water Chemistry

	As	Si	PO_4^{3-}	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}
Well	**ppb**	ppm	ppm	ppm	ppm	ppm	ppm	ppm
12	**15.3**	11.1	<0.05	0.0	43.2	15.2	26.9	1.8
13	**0.9**	5.6	<0.05	2.3	46.3	11.7	1.3	1.1
14	**102.4**	29.9	<0.05	28.5	41.4	12.9	61.8	15.9
15	**71.3**	19.6	<0.05	47.3	60.1	13.7	77.6	5.8
16	**15.9**	10.8	<0.05	30.2	21.2	7.5	17.6	9.4
17	**14.4**	22.0	<0.05	58.5	44.2	11.9	48.4	9.3
18	**20.9**	10.4	<0.05	110.8	54.2	10.6	11.1	3.8
19	**13.3**	13.1	<0.05	30.67	31.4	12.4	20.0	5.8
20	**12.4**	23.7	<0.05	13.42	24.0	3.6	57.6	4.6
21	**8.9**	25.7	<0.05	12.95	29.0	5.8	102.2	3.7

South Dakota Water Chemistry

	As	Si	PO_4^{3-}	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}
Well	**ppb**	ppm	ppm	ppm	ppm	ppm	ppm	ppm
22	**30.8**	13.1	<0.5	433.6	197.5	68.9	52.6	4.0
23	**2.2**	4.1	<0.5	735.4	7.5	2.3	816.1	7.0
24	**34.1**	13.6	<0.5	211.5	49.8	12.2	309.2	9.1
25	**13.2**	13.0	<0.5	178.5	113.4	34.7	40.5	7.9
26	**10.4**	32.8	<0.5	20.6	24.1	3.2	70.3	10.8
27	**12.4**	31.8	<0.05	8.6	44.7	7.3	14.3	11.3
28	**10.2**	5.3	<0.05	16.1	44.0	22.0	7.1	3.4
29	**4.0**	5.0	<0.05	5.2	58.7	26.6	1.7	1.5
30	**13.4**	13.0	0.2	6.4	11.1	2.5	8.6	2.1
31	**19.0**	7.1	<0.05	9.5	46.8	7.9	2.3	1.0

Utah Water Chemistry

	As	Si	PO_4^{3-}	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}
Well	**ppb**	ppm	ppm	ppm	ppm	ppm	ppm	ppm
32	**14.0**	25.7	<0.05	157.76	69.8	35.5	422.1	23.4
33	**11.7**	8.5	<0.05	226.24	95.2	46.5	217.3	10.6
34	**14.1**	9.2	<0.05	24.80	4.9	1.7	52.5	1.0
35	**10.9**	10.0	<0.05	17.17	5.0	2.4	54.8	1.2
36	**13.8**	15.6	<0.05	33.89	14.5	6.0	78.0	1.9
37	**10.0**	18.1	<0.05	28.14	16.3	9.4	53.9	3.4
38	**11.6**	21.7	<0.05	117.04	37.2	21.1	78.1	4.7
39	**9.0**	17.5	<0.05	113.70	27.3	14.0	59.0	4.2
40	**10.8**	4.1	<0.05	12.53	15.2	5.2	3.8	1.0
41	**18.3**	8.2	0.25	34.34	55.1	11.1	11.7	1.9
42	**19.8**	6.0	0.28	36.44	44.3	10.6	9.6	1.6
43	**21.1**	3.1	<0.05	47.79	1.7	0.4	77.8	0.8
44	**8.1**	15.5	<0.05	2.47	17.5	4.5	9.1	2.0

Wyoming Water Chemistry

	As	Si	PO_4^{3-}	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}
Well	**ppb**	ppm	ppm	ppm	ppm	ppm	ppm	ppm
45	**1.7**	5.9	<0.05	138.0	76.4	20.3	13.7	2.6
46	**1.1**	8.3	<0.05	174.3	94.6	34.4	29.1	1.7
47	**0.4**	5.7	<0.05	34.9	43.2	12.9	11.9	1.7
48	**<0.05**	9.2	<0.05	389.1	140.1	19.1	44.1	2.3
49	**<0.05**	7.4	<0.05	189.9	60.7	5.9	82.1	1.3
50	**0.4**	10.0	<0.05	313.4	100.4	41.4	62.2	1.9
51	**<0.05**	4.8	<0.05	241.6	30.0	7.9	193.8	1.8
52	**5.5**	5.0	<0.05	260.7	5.3	0.0	208.1	0.4
53	**15.3**	31.5	<0.05	41.8	19.5	10.5	57.9	6.7

Results

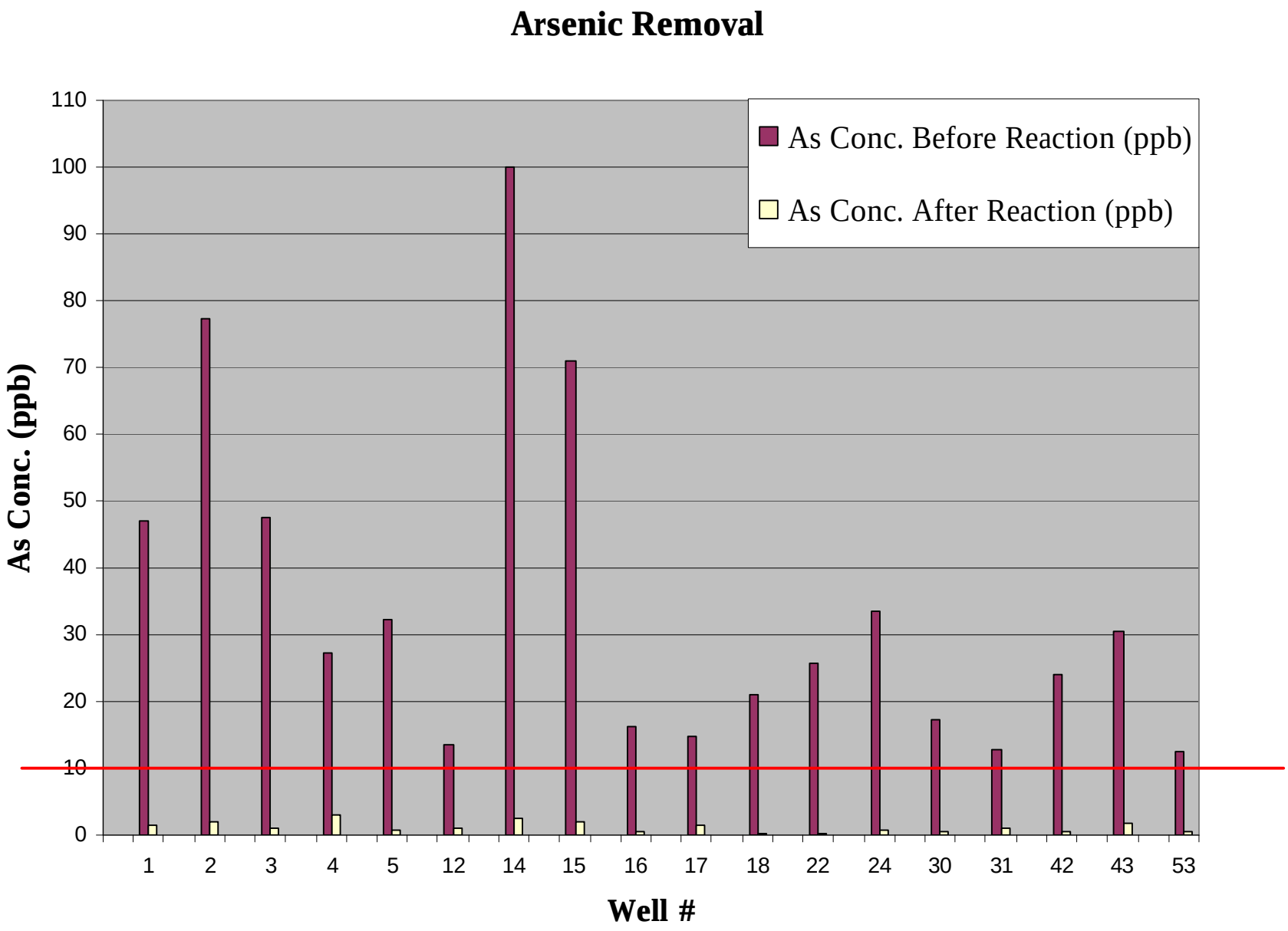
- Collected a total of 53 samples from Region 8
- Sampling results from CO, MT, SD, UT, and WYO suggest that a wide range of arsenic concentrations exists
  - As concentrations ranged from <0.05 ppb to 102.4 ppb
- pH from these samples ranged from 6.54 to 8.69
- 66% of the total samples taken exceeded 10 ug/L

Outreach Program

- Relay water chemistry to network partners to allow better understanding of their water
- Distribution of an arsenic pamphlet that outlines causes of contamination and potential risks of arsenic in drinking water
- Establish a dialogue between network partners and professionals within the field

Arsenic Removal Method

- Samples that exceeded 10 ug/L MCL limit
- Reacted 17 samples from CO, MT, SD, UT, WYO
  - 5 from CO
  - 5 from MT
  - 4 from SD
  - 2 from UT
  - 1 from WYO
- Reacted samples for 27 minutes with ARTI 64® particles on a mechanical shaker then 3 minutes in centrifuge
- Filtered samples through .45 micron filter paper
  - Then analyzed for As with ICP-MS


Arsenic Removal
As Conc. Before Reaction (ppb)
As Conc. After Reaction (ppb)
As Conc. (ppb)
110
100
90
80
70
60
50
40
30
20
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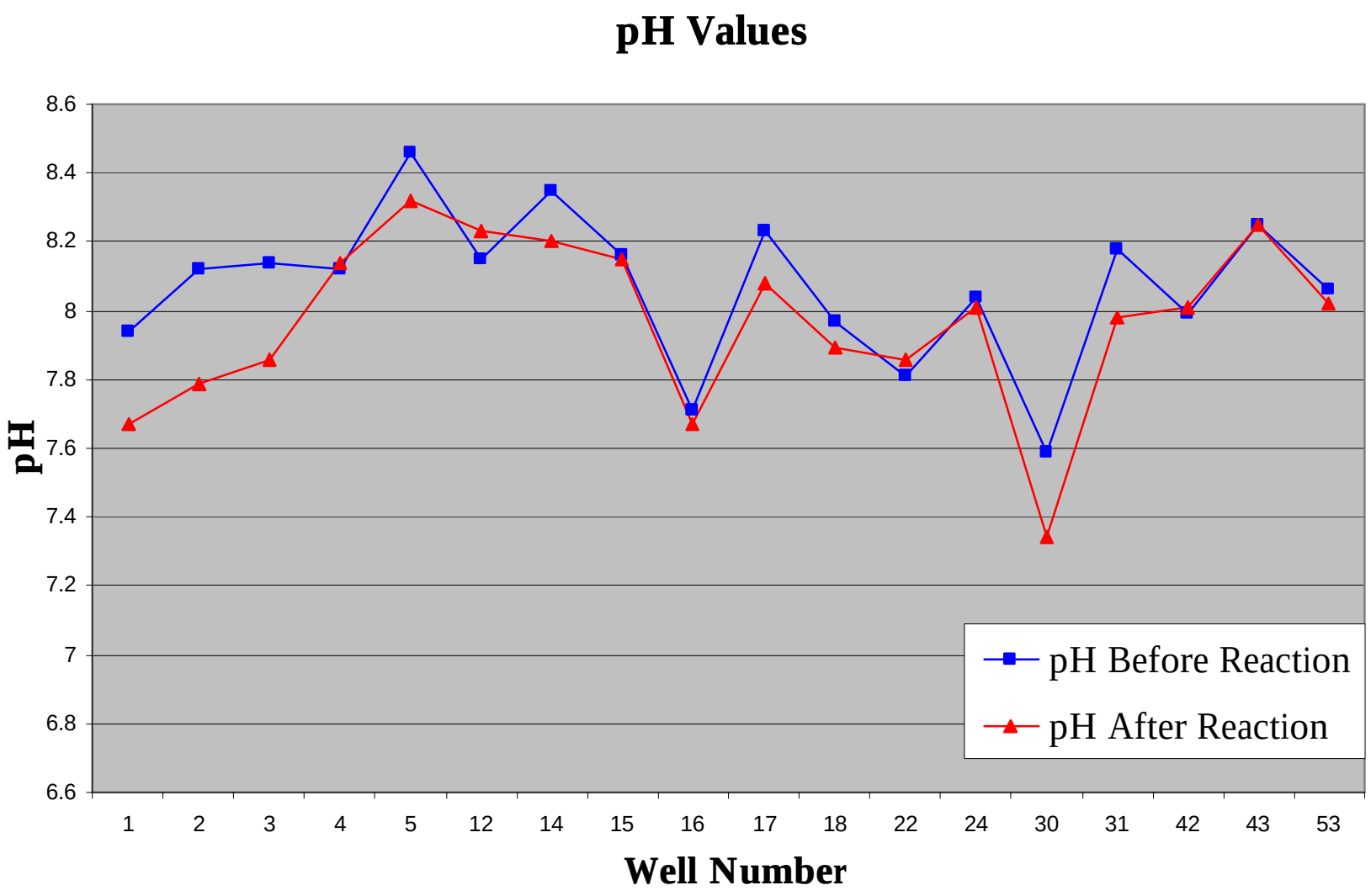
43
53
Well #


pH Values
8.6
8.4
8.2
8
7.8
7.6
7.4
7.2
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6.8
6.6
pH
1
2
3
4
5
12
14
15
16
17
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22
24
30
31
42
43
53
Well Number
pH Before Reaction
pH After Reaction

ARTI 64® Particles

- Simple adsorption / desorption process
- Reversible and arsenic waste easily trapped
- No pre-oxidation of As III to As V
- No pre or post pH alterations needed

Removal Efficiency

- Averaged 95% removal efficiency of the total Arsenic in each sample tested
  - Suggests that ARTI-64® particles are not affected by regional differences
- Minimal changes in pH
- Unaffected by competing ions in water i.e. phosphate, sulfate, and silicate
- Doesn’t affect treated water quality

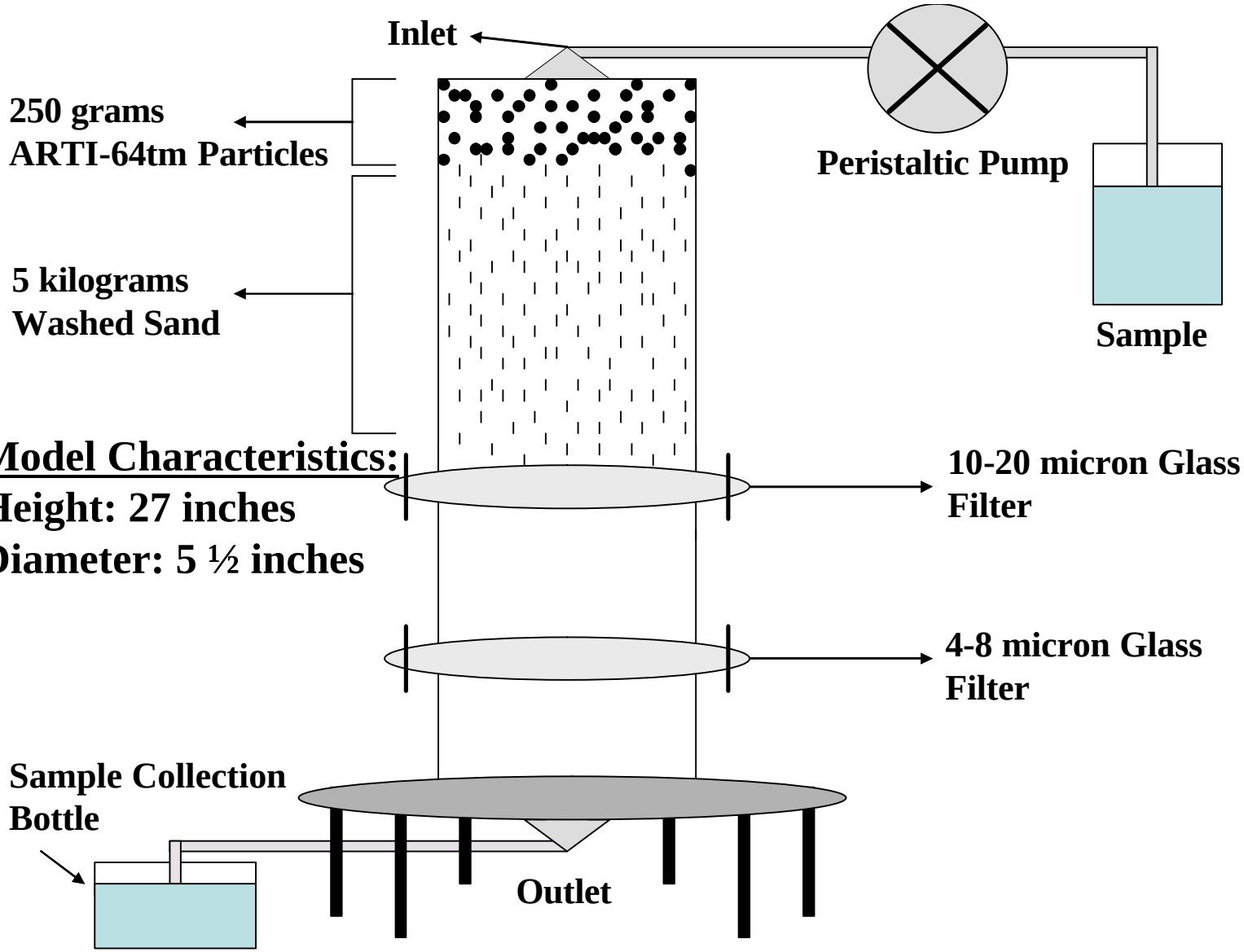
Conclusions

- We are trying to increase awareness of arsenic contamination within the region
- Established a Network of Partners within the region
- Potential for cost-effective remediation for small communities or private homes

Further Research

- Continue to work with Network Partners
- Increase Network of Partners to collect more water samples and create a larger arsenic database for regional states
- Establish effective continuous flow-through arsenic removal method
  - More applicable for real world model
  - Compare with previous results of batch testing

Flow-Through Column



Model Characteristics:

Height: 27 inches

Diameter: 5 ½ inches

Acknowledgements

- Dr. KJ Reddy
- Viswatej Attili
- Private well owners throughout the region who allowed me access to sample their water and participate in the study
- Regional partners