Characterization of Coal Combustion By-products for the Re-Evolution Of Mercury into Ecosystems

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Today's Presentation

- Background
- Program objectives
- Experimental design
- Results & Conclusions

Background

- Typical mercury concentration in coal is 0.05 to 0.20 µg/g
- Volatilized during combustion
- Coal mercury fate after combustion
  - Bottom ash
  - Fly ash
  - FGD solids
  - Stack gas
- Previous study by CONSOL
- What is the fate of mercury collected on fly ash and FGD solids?

Program Objectives

- Address concern for mercury evolution from coal combustion by-products into ecosystems
- Screening program: Gather data on materials from power plants with various
  - Coal sources
  - Air pollution control systems, including some with scrubbers
  - By-product end uses

Experimental Design

- Sample types
  - Coal, bottom ash, fly ash, FGD sludge and spray dryer solids
- Leaching tests using standard methodology
- Volatility tests of our own design
- Groundwater sampling
  - Active FGD disposal site
  - Active fly ash slurry impoundment

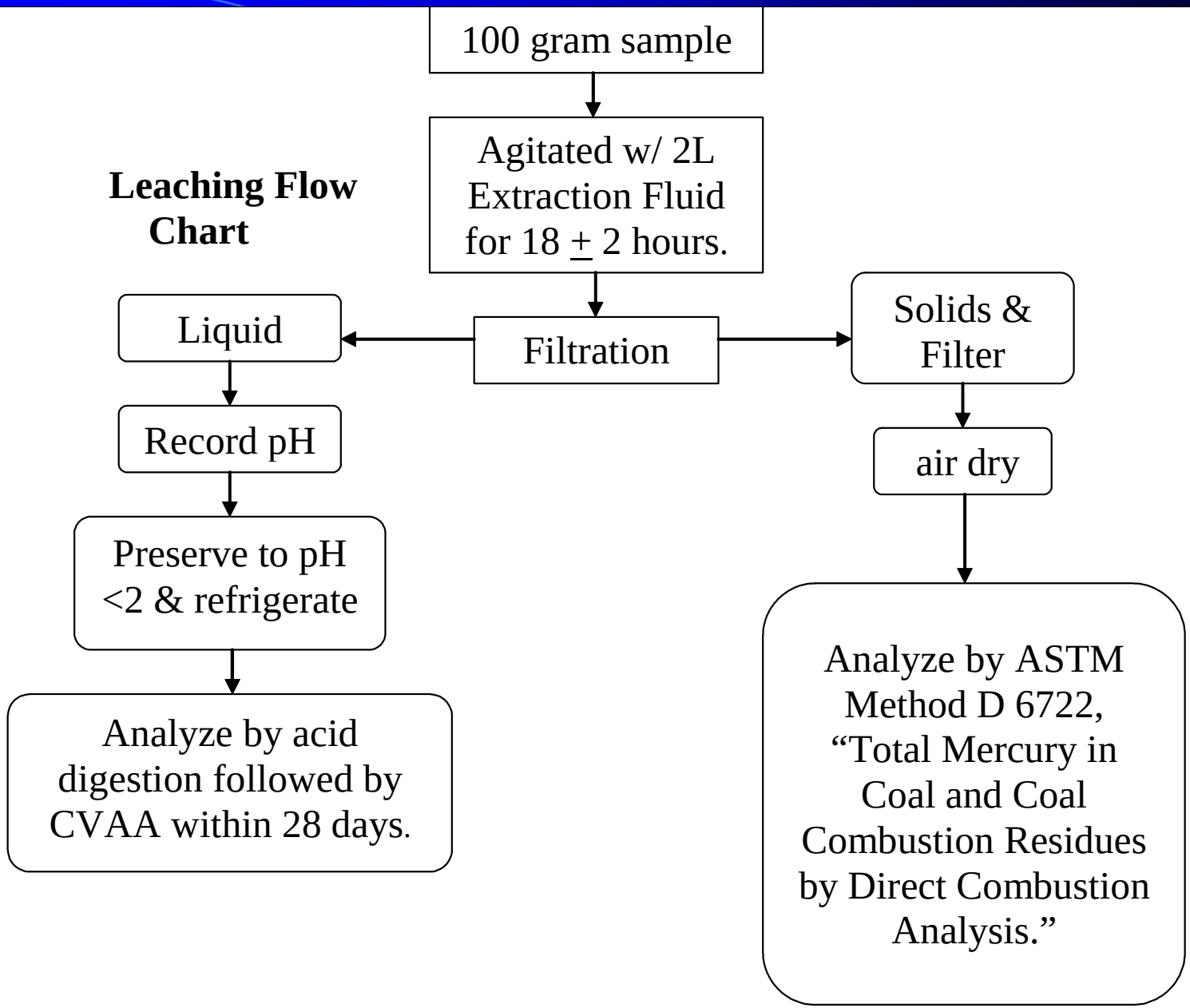
Sample Matrix

Plant Code	Coal Source	Particulate Control	FGD Type	Coal	Bottom Ash	Fly Ash (from ESP or Fabric Filter)	FGD Sludge or Spray Dryer Ash	Fixated FGD Sludge	Synthetic Aggregate Product	Forced Oxidation Gypsum
1	Pittsburgh Seam	ESP	Mg/Lime	X		X	X	X		
2	Pittsburgh Seam	ESP	Forced Oxidation	X	X	X	X			
3	Ohio 5, 6, or 11	ESP	Mg/Lime	X	X	X		X		
4	Illinois 6	ESP	Natural Oxidation	X		X	X	X		
5	Eastern Low Sulfur Bituminous	Baghouse	Lime Spray Dryer	X	X		X			
6	Illinois/W KY Blend	ESP		X		X				
7	Powder River Basin	Baghouse		X		X				
8	Powder River Basin	Baghouse								
9	Powder River Basin	ESP		X	X	X				
9a	Powder River Basin	ESP (w/carbon injection)				X				
11	Appalachian Bituminous	Baghouse	Circulating Dry Scrubber				X			
12	Pittsburgh Seam	ESP	Mg/Lime	X	X	X	X			
13	Pittsburgh Seam	ESP	Mg/Lime	X	X	X	X			X
14	Eastern Low Sulfur Bituminous	Baghouse	Lime Spray Dryer			X	X		X	
15	Pittsburgh Seam	ESP	Inhibited Oxidation				X		X	
16	Pittsburgh Seam	ESP			X	X				

Leaching Tests

- EPA Method 1311 & ASTM Method D3987
- Leaching is conducted at three pH values.
  - Acetic acid buffered to a pH of 2.8
  - Acetic acid buffered to a pH of 4.9
  - Deionized water

Leaching Flow Chart



Leaching Results – Fly Ash

Plant ID #	Coal Source	Mercury in Solids, mg/kg as det.	Mercury in Leachate, ng/mL		
			pH 2.8	pH 4.9	DI H20
1	Pittsburgh Seam	0.34	<1.0	<1.0	<1.0
3	Ohio 5, 6, or 11	0.08	<1.0	<1.0	<1.0
4	Illinois 6	0.07	<1.0	<1.0	<1.0
4	Illinois 6	0.08	<1.0	<1.0	<1.0
4	Illinois 6	0.06	<1.0	<1.0	<1.0
6	Illinois/W KY Blend	0.25	<1.0	<1.0	<1.0
6	Illinois/W KY Blend	0.14	<1.0	<1.0	<1.0
6	Illinois/W KY Blend	0.58	<1.0	<1.0	<1.0
7	Powder River Basin	1.49	<1.0	<1.0	<1.0
9	Powder River Basin	0.14	<1.0	<1.0	<1.0
9	Powder River Basin	0.12	<1.0	<1.0	<1.0
9	Powder River Basin	0.08	<1.0	<1.0	<1.0
9a	Powder River Basin	0.73	<1.0	<1.0	<1.0
9a	Powder River Basin	1.2	<1.0	<1.0	<1.0
13	Pittsburgh Seam	0.08	<1.0	<1.0	<1.0
16	Pittsburgh Seam	0.47	<1.0	<1.0	<1.0
16	Pittsburgh Seam	0.25	<1.0	<1.0	<1.0

Leaching Results – FGD Sludge

Not Fixated

Plant ID #	Coal Source	Scrubber Type	Mercury in Solids, mg/kg as det.	Mercury in Leachate, ng/mL		
				pH 2.8	pH 4.9	DI H20
1	Pittsburgh Seam	Mg/Lime	0.40	10.9	5.2	<1.0
4	Illinois 6	Limestone, Natural Oxidation	0.25	<1.0	2.0	<1.0
4	Illinois 6	Limestone, Natural Oxidation	0.21	1.4	<1.0	<1.0
4	Illinois 6	Limestone, Natural Oxidation	0.21	<1.0	1.0	<1.0
15	Pittsburgh Seam	Limestone, Inhibited Oxidation	0.65	1.3	<1.0	<1.0

Fixated

Plant ID #	Coal Source	Scrubber Type	Mercury in Solids, mg/kg as det.	Mercury in Leachate, ng/mL		
				pH 2.8	pH 4.9	DI H20
1	Pittsburgh Seam	Mg/Lime	0.34	2.6	<1.0	<1.0
1	Pittsburgh Seam	Mg/Lime	0.39	<1.0	<1.0	<1.0
1	Pittsburgh Seam	Mg/Lime	0.36	<1.0	<1.0	<1.0
1	Pittsburgh Seam	Mg/Lime	0.30	1.6	<1.0	<1.0
3	Ohio 5, 6, or 11	Mg/Lime	0.47	6.6	2.5	<1.0
3	Ohio 5, 6, or 11	Mg/Lime	0.52	6.6	1.7	<1.0
3	Ohio 5, 6, or 11	Mg/Lime	0.48	5.7	1.5	<1.0
3	Ohio 5, 6, or 11	Mg/Lime	0.90	6.1	<1.0	<1.0
4	Illinois 6	Limestone, Natural Oxidation	0.26	<1.0	<1.0	<1.0

Leaching Results – FGD Sludge

Effect of Fixation

Plant	% of Original Mercury Leached with pH 2.8 Solution		% of Original Mercury Leached with pH 4.9 Solution	
	Unfixated	Fixated	Unfixated	Fixated
1	54%	0-15%	26%	0%
4	0-13%	0%	0-16%	0%

Leaching Results

Dry Scrubber Ash

Plant ID #	Coal Source	Mercury in Solids, mg/kg as det.	Mercury in Leachate, ng/mL		
			pH 2.8	pH 4.9	DI H20
11	Appalachian Bituminous	0.33	<1.0	<1.0	<1.0
11	Appalachian Bituminous	0.33	<1.0	<1.0	<1.0
14	Eastern Low-Sulfur Bituminous	0.52	<1.0	<1.0	<1.0

By-product Re-use Samples

Plant ID #	Coal Source	Sample Type	Mercury in Solids, mg/kg as det.	Mercury in Leachate, ng/mL		
				pH 2.8	pH 4.9	DI H20
13	Pittsburgh Seam	Forced Oxidation Gypsum	0.02	<1.0	<1.0	<1.0
14	Eastern Low-Sulfur Bituminous	Synthetic Aggregate	0.39	<1.0	3.9	<1.0
15	Pittsburgh Seam	Synthetic Aggregate	0.39	<1.0	<1.0	<1.0

Leaching Results

Bottom Ash

Plant ID #	Coal Source	Mercury in Solids, mg/kg as det.	Mercury in Leachate, ng/mL		
			pH 2.8	pH 4.9	DI H20
3	Ohio 5, 6, or 11	0.04	<1.0	<1.0	<1.0
13	Pittsburgh Seam	0.01	<1.0	<1.0	<1.0

Coal Samples

Plant ID #	Coal Source	Mercury in Solids, mg/kg as det.	Mercury in Leachate, ng/mL		
			pH 2.8	pH 4.9	DI H20
3	Ohio 5, 6, or 11	0.28	<1.0	<1.0	<1.0
3	Ohio 5, 6, or 11	0.23	<1.0	<1.0	<1.0
13	Pittsburgh Seam	0.16	<1.0	<1.0	<1.0

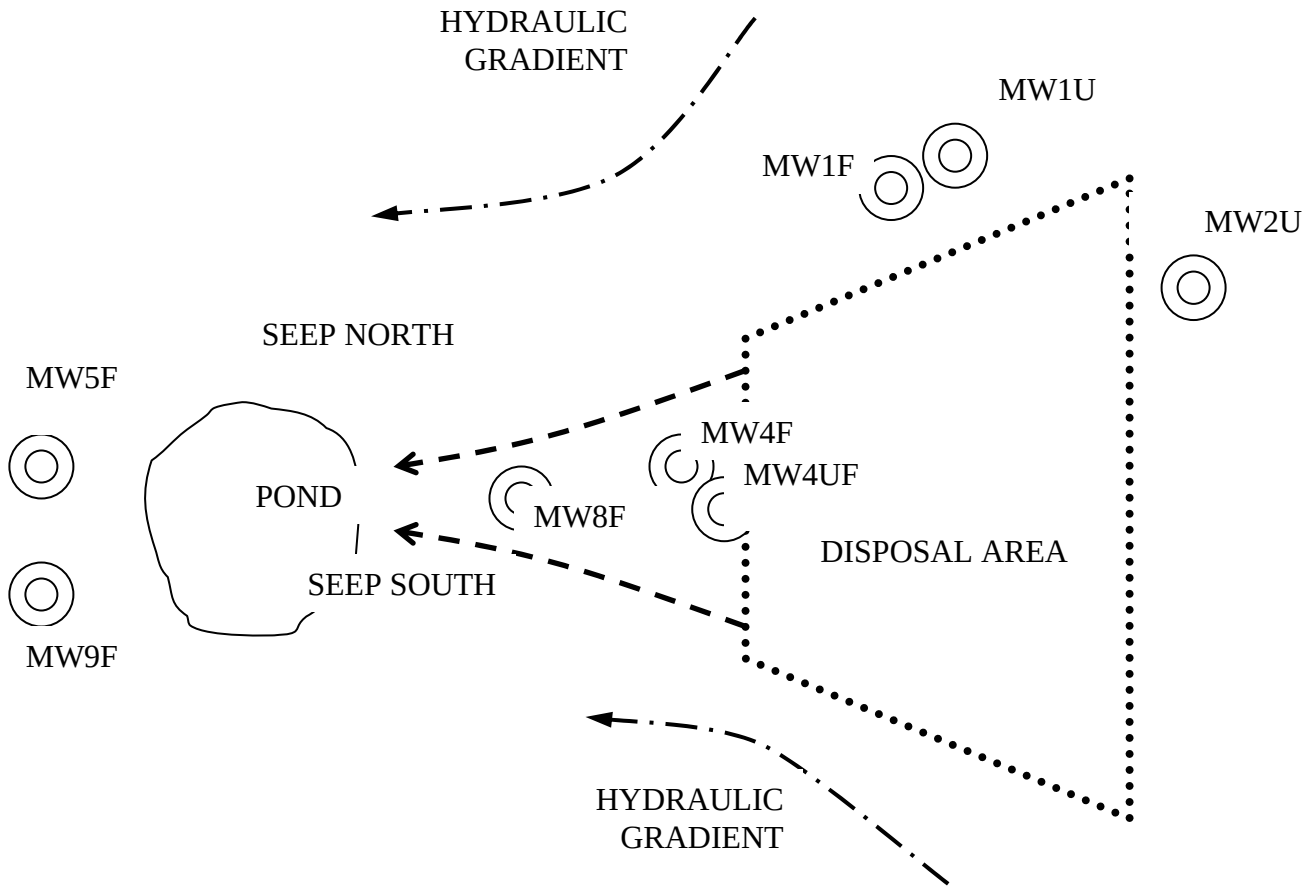
Volatilization Tests

- Samples of ash, FGD solids, spray dryer solids, aggregate, cement, and wallboard were tested.
- Two temperatures: 100 °F and 140 °F
- Continuous Hg-free N_2 purge
- Samples held for six months, analyzed by ASTM method D 6722
- Experimental problems; samples absorbed mercury; results not meaningful

Groundwater Study

- To determine the potential for mercury release from an active FGD sludge disposal site and an active fly ash slurry impoundment.
- Sampling sites
- Samples collected quarterly
- Sample analysis

FGD Active Disposal Area



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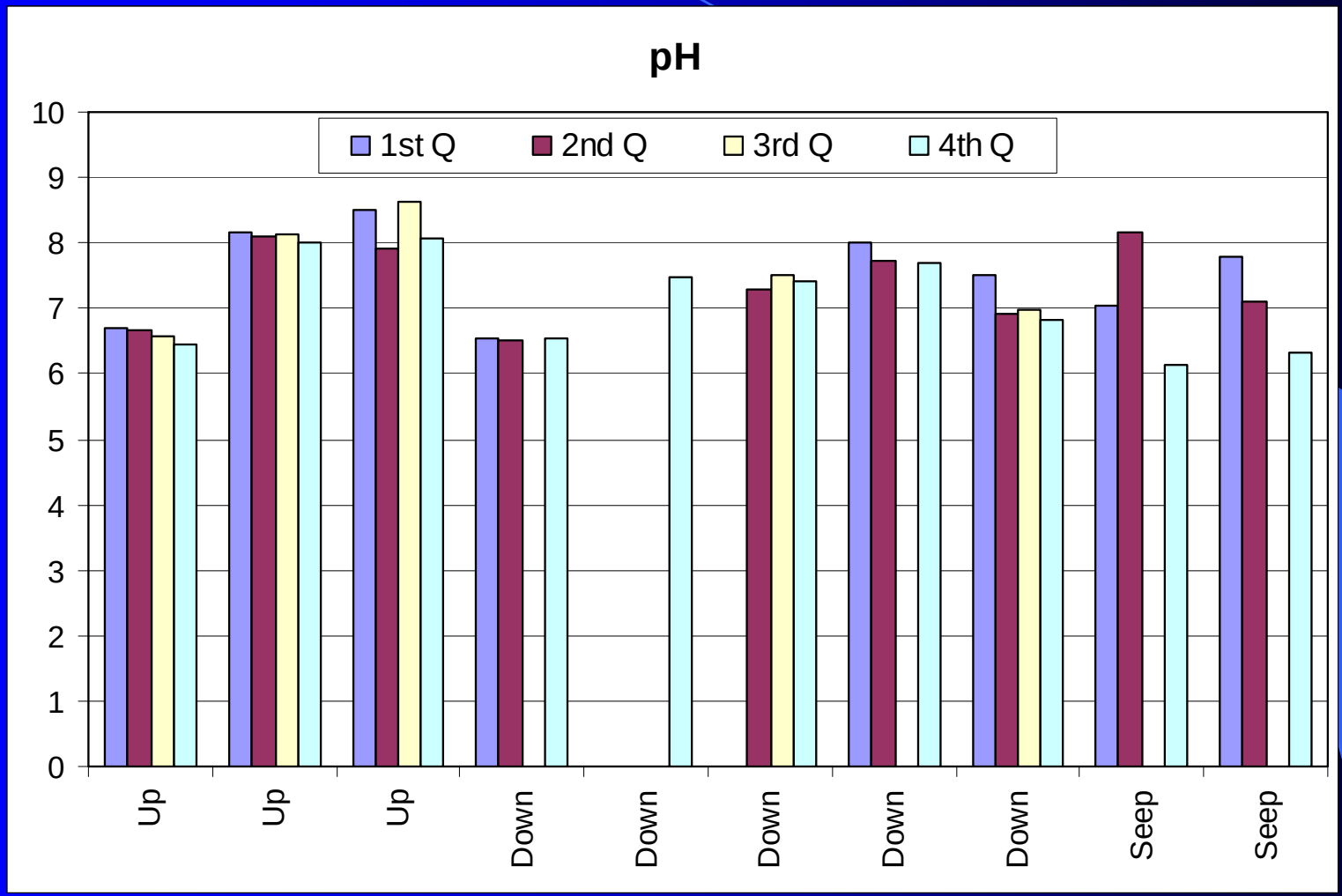
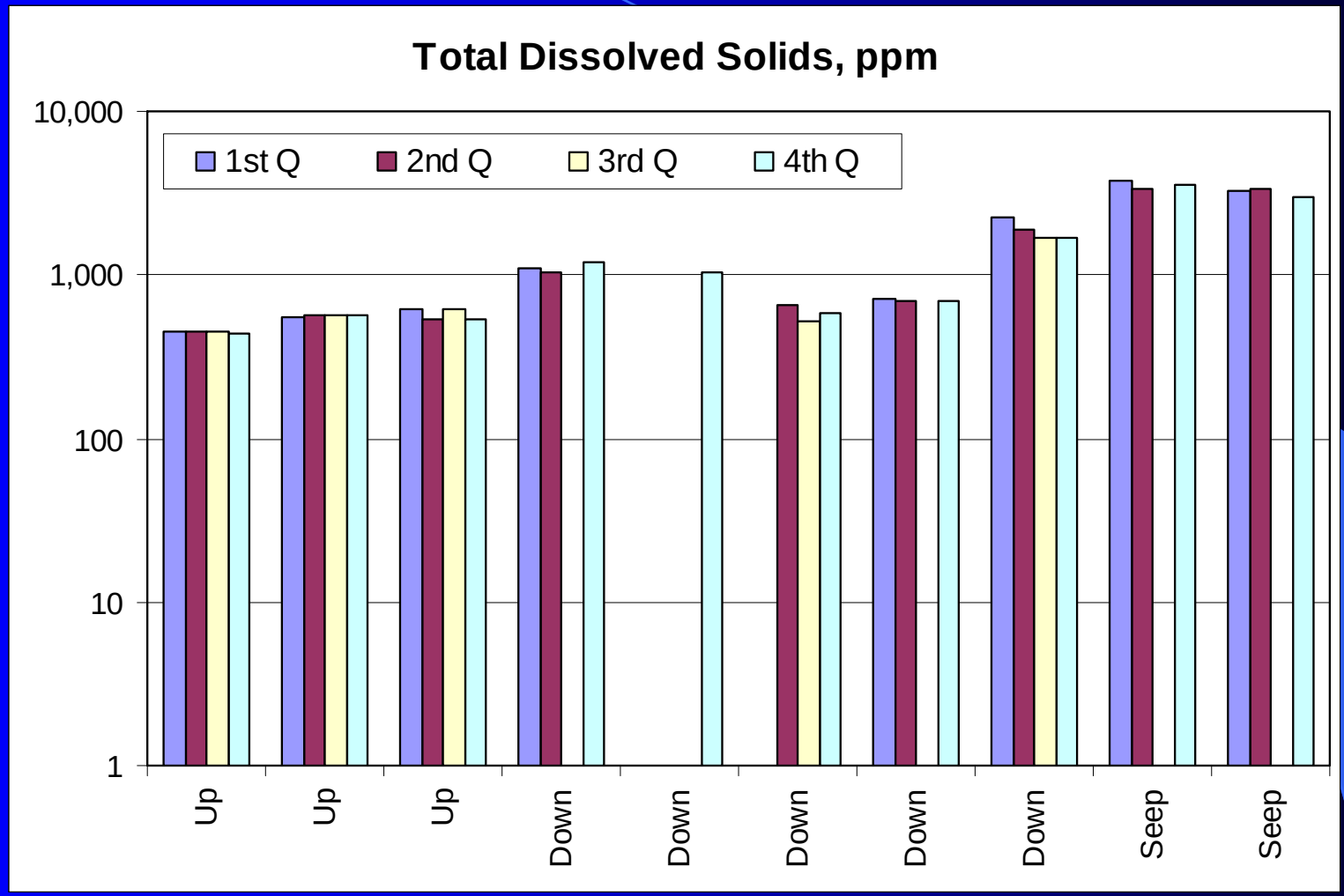
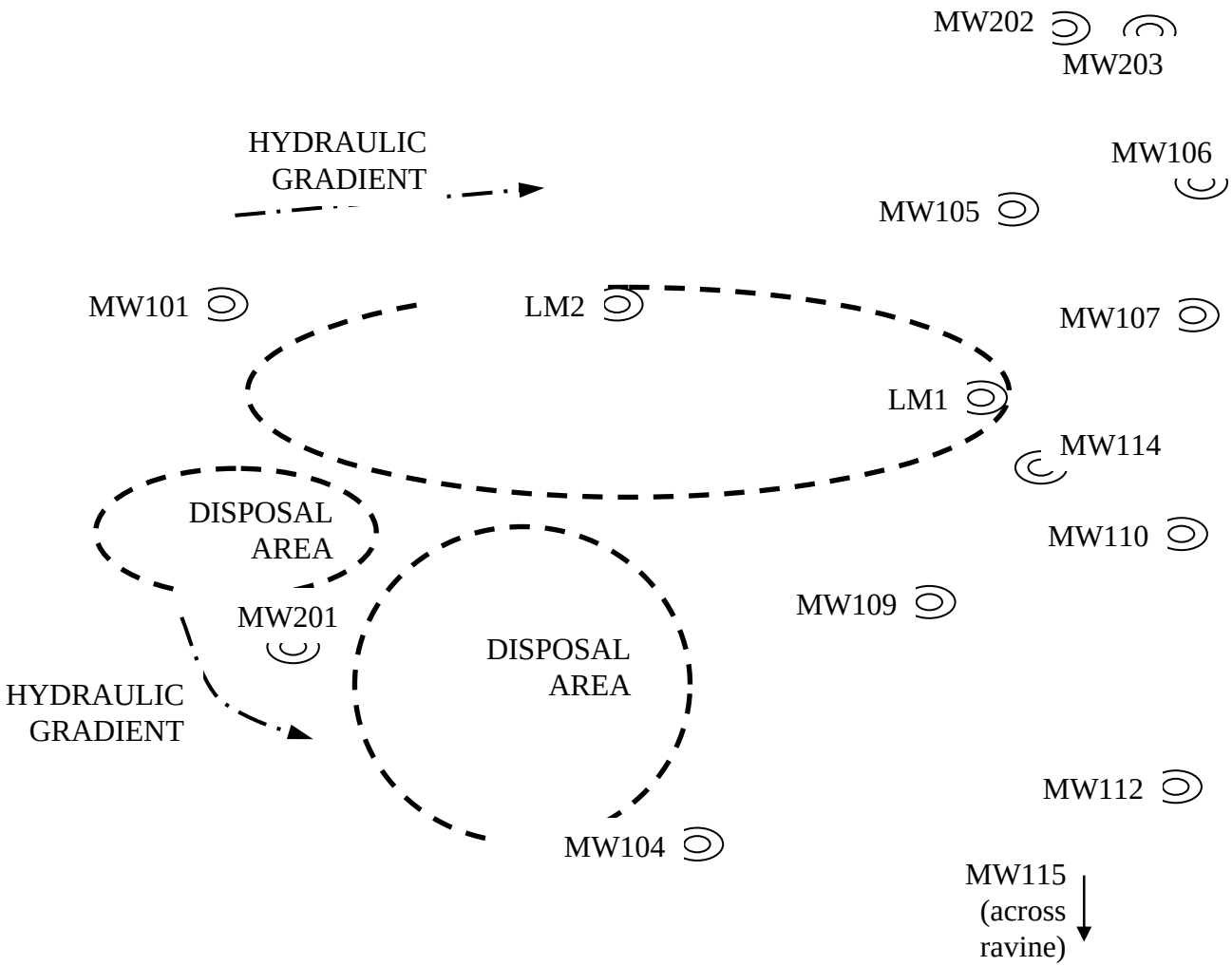


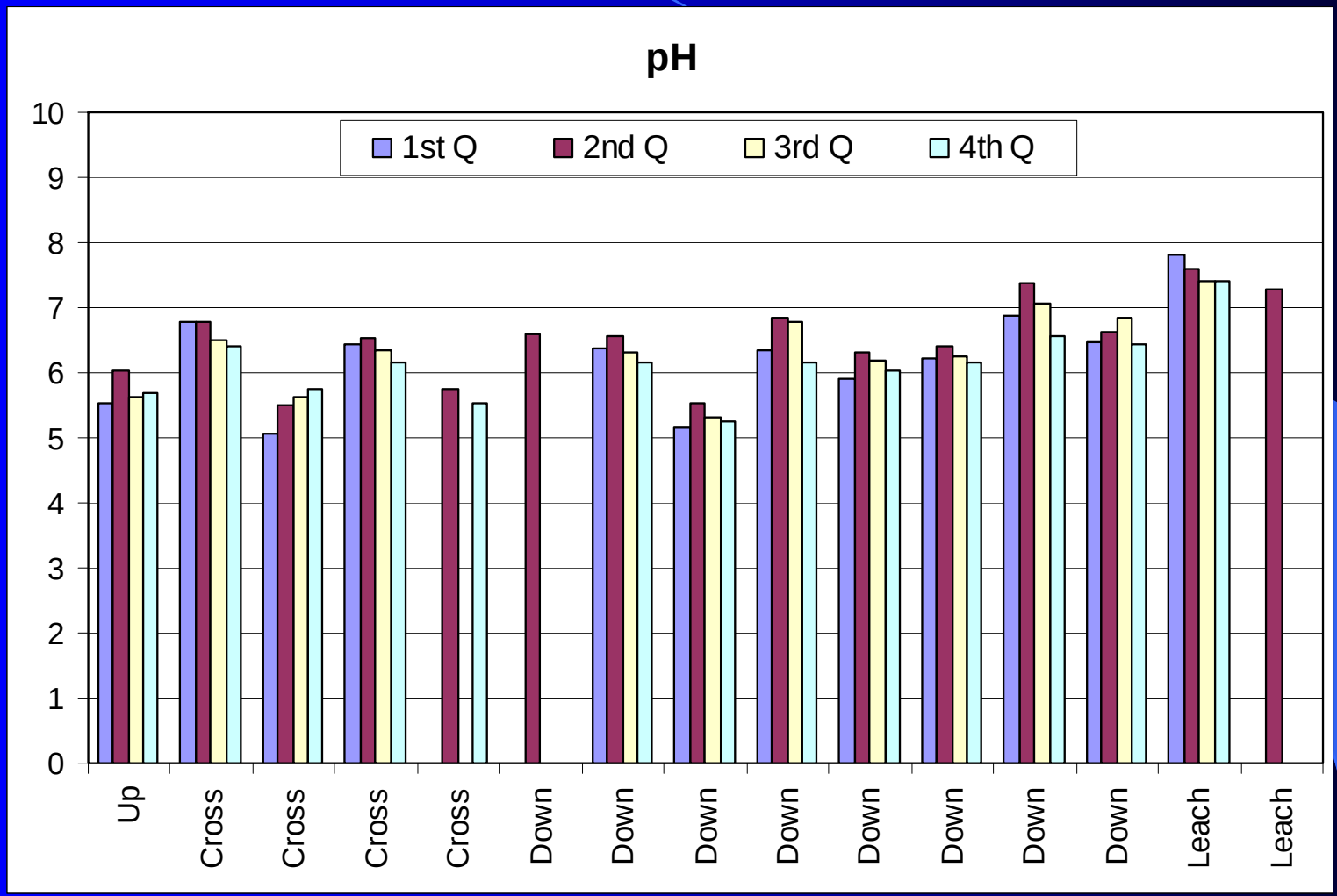
FGD Active Disposal Area



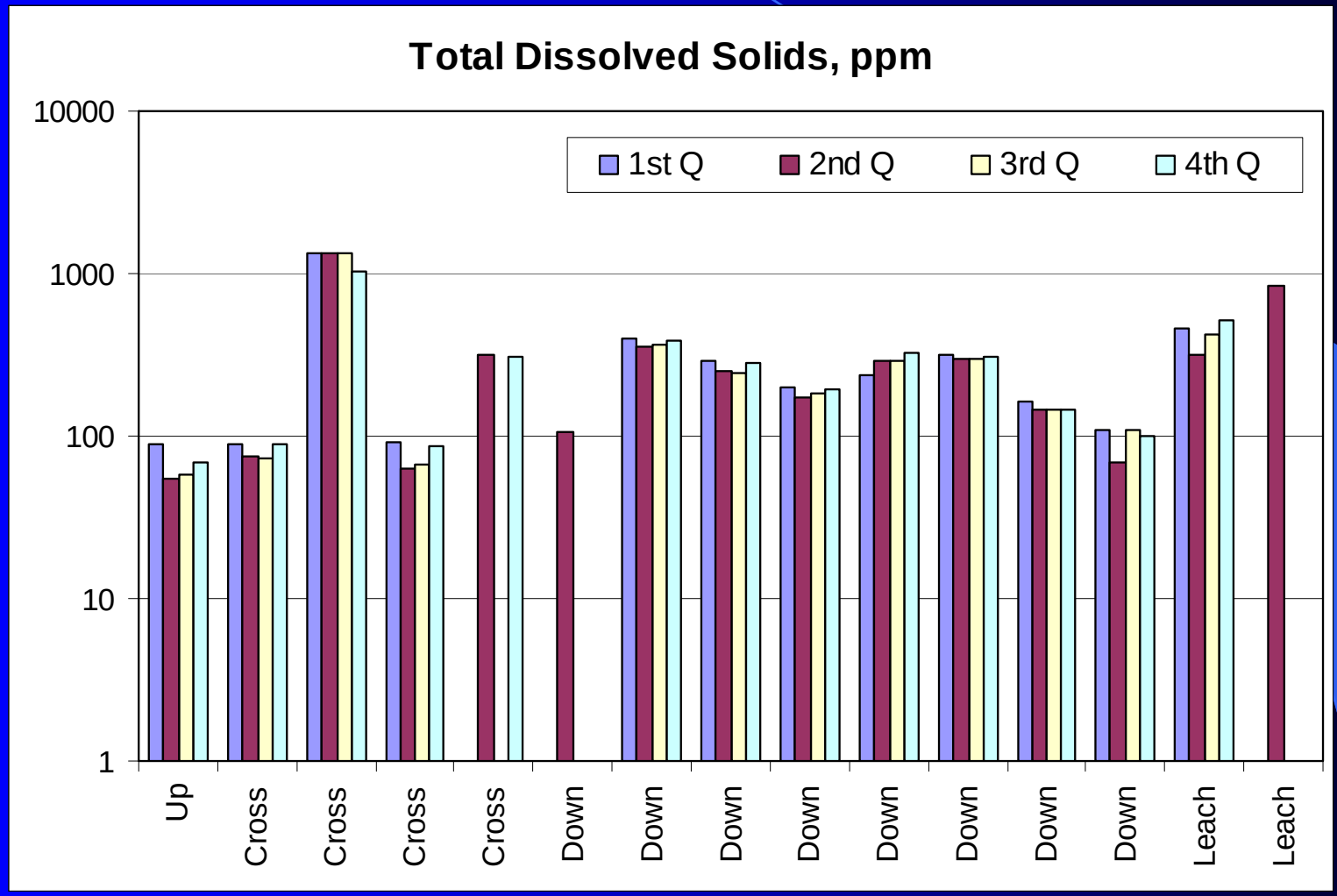
Active Fly Ash Slurry Impoundment



Active Fly Ash Slurry Impoundment



Active Fly Ash Slurry Impoundment



FGD Active Disposal Area
Ground Water Sampling Results

No detectable mercury (<1.0 ng/mL) was found in any monitoring well sample

Fly Ash Active Slurry Impoundment
Ground Water Sampling Results

No detectable mercury (<1.0 ng/mL) was found in any monitoring well sample

Conclusions

- Leaching Tests
  - Mercury did not leach from fly ash, SDA ash, FOG, coal, or bottom ash
  - Mercury was detected at very low concentrations in acidic leachates from all of the fixated and most of the unfixated FGD sludge samples
  - Mercury was not detected from any sample when leached with DI water
- Volatilization Tests
  - Could not detect mercury loss from most samples
  - Sampling & storage difficulties
- Ground Water Monitoring
  - Mercury was not detected in any water samples collected at an active FGD disposal site and an active fly ash slurry impoundment

Acknowledgments

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